ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF ELECTRICAL ENGINEERING AND COMPUTING

Department of Computing

A MASTER'S THESIS

ON

Face Recognition using Principle Component Analysis and Linear Discriminant Analysis

MASTER OF SCIENCE IN SOFTWARE ENGINEERING

BY:

Hadush mesfin

GSR/02974/07

ADVISOR: Prof. Dr.Chung

January, 2018

ASTU

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF ELECTRICAL ENGINEERING AND COMPUTING

A MASTER'S THESIS

ON

Face Recognition using Principle Component Analysis andLinear Discriminant Analysis

Name and signature of members of the examining board

Name	Signature	Date
______________________________	______________________	____________________
Advisor		
______________________________	______________________	____________________
External Examiner		
______________________________	______________________	____________________
Internal Examiner		

ACKNOWLEDGMENT

First I would like to thank the almighty GOD for giving me the strength and making me have a set of distinctive goals in my life.

I would like to express my genuine gratitude and appreciation to my advisor **Prof. Dr.** Chung for his continuous help, guidance,and support from the start to the end of the thesis work. He directed me to explore and understand the subject matter as well as the way of writing of this thesis. Without his help and sincerity approach, this work would not have been completed. I am also extending to **Dr. AnandRaji**forhis support during title selection. He had supported me many latest works related to my study and even necessary books for my future study. He is honestly responding to all my requests on time even he has agreat role in writing the comments. I also offer my sincere gratitude to all Adama Science and Technology University community and to my colleagues and friends for the brotherly love shown me during my period of study in Adama Science and Technology University.

Finally, I would like to thank all who wished me success especially my parents and friends for being by my side in all my ups and downs.

// Abstract

Now day face recognition is one of the most dominant biometrics used in the area of information security, law enforcement, access control, surveillance and multimedia search engine. The non-intrusive nature of this technology makes more advantage than other biometric technologies. In the last few years, a number of researcheson face detection and recognition have been conducted by researchers in different fields claimed to have satisfactory results in the preceding researches. However, until now there is no a single face detection and recognition method that satisfy in all circumstances. What makes to be unsatisfactory is that it could be affected by external and internal factors such as light variation, expression variation, angle variation, image background, age variation, and motion. These variations can be reduced by applying various image preprocessing techniques.

This thesis proposes and describes a research attempt at designing and developing a prototype face detection and recognition system. The system is developed using the Java programing language with the help of OpenCV 3.1.0 image processing library.

For face detection purpose, we have been used the Viola and Jones method and its performance was evaluated in both real-time and non-real-time environment. The accuracy of the detector is tested using images from Carnegie Mellon University and Massachusetts Institute of Technology(CMU-MIT), Labeled Faces in the Wild (LFW), image from Faculty of Industrial Engineering (FEI) and self-preparedface databases and produces agood result. The study also considers various image preprocessing techniques such as histogram equalization, Bilateral Filter, face masking, and image resizing to increase the accuracy the recognizer.

The principal component analysis (PCA) and linear discriminant analysis (LDA)dimension reduction techniques were used to extract image information and classified the image based on distance measurement techniques. The study also conducts comparative analyses of these two methods to determine their relative strengths, weaknesses,and suitability for face recognition.

The experiment resultsof masked FEI, ORL and Self-prepared datasets produce an accuracy rate of 95%, 91%, and 91.25% respectively using PCA method. And experiment result of LDA method produce accuracy rate of 96%, 86.25%, 83.75% for the three different database using masking techniques.The results areencouraging and with more optimization works better results can be achieved

Keyword:face recognition, OpenCV, biometrics, computer vision

Contents

List of Figures

List of Tables

ACRONYMS

AAMActive Appearance Model

ASMActive Shape Model

ATMAutomated Teller Machine

CMU-MIT Carnegie Mellon University and Massachusetts Institute of Technology

CS-LBP Centre Symmetric Local Binary Patterns

FEI Faculty of Electrical Engineering and Information Technology

HMMHidden Markov Model

H-NPCA hierarchical Nonlinear PCA

ICA Independent Component Analysis

JPEGJoint Photographic Experts Group

Kernel-LDA Kernel Linear Discriminant Analysis

Kernel-PCA Kernel Principal Component Analysis

LBPLocal Binary Pattern

LDA Linear Discriminant Analysis

LFW Labeled Faces in the Wild

MLP Multiple Layer Perceptron

MRRMiss Recognition Rate

OpenCVOpen Source Computer Vision Library Open Source Computer Vision Library

ORL Olivetti Research Laboratory

PCA Principal Component Analysis

PNGPortable Network Graphics

PRR Positive Recognition Rate

RFID Radio Frequency Identification

SGBM spatial Gaussian Bessel mixtures

SIFT Scale Invariant Feature Transform

TMRF Total Miss-Recognized faces

TNF Total Number of faces

TPRtotal number of positively recognized faces

CHAPTER ONE

1. INTRODUCTION

This chapter explains the general overview of human identification, then it presents the overall objective, a significance of the study, scope, and limitation of the thesis and problem that has to be addressed and finally how the thesis organized.

1.1 Overview of Human Identification

Various human physiological and behavioral traits were used to identify person's identity. A field of computer science that used to determine the identity with respect to different characteristics is called biometrics. This field of study becomes significant since people are getting understood the terms of security and privacy [1]. As various evidences shown,biometric traitsare used for personal identification since the ancient Egyptian period. But it has been a hot research area since the 19th century that the field of biometrics widely used for personal identification and security-related issues [2].

According to ARPITA PATRA [3],any human physiological and behavioral characteristic can be treated as a biometric as long as it satisfies universality, distinctiveness, permanence, and collectability. Fingerprint, face recognition, iris recognition, signature recognition, and hand geometry are some methods that satisfy the above-mentioned criteria.

In recent years, face recognition has been studied by researchers from a diverse field of studies such as psychophysical sciences and those from different areas of computer sciences [11]. The common interest among researchers working in diverse fields is motivated by the human remarkable ability to recognize people [4]. According to [4, 12, 13, 65], face recognition has been described as the most convenience biometric identification systems, due to a number of significant advantages over other methods of identification.

Currently,face recognition systems are incorporated with many applications include security system, criminal identification, image and film processing [5], automated video surveillance and other areas. But, in realistic application scenarios, a digital image that contains face can have a complex background which is difficult to differentiate from the face region. In addition, pose variation, illumination variation, and variation in facial expression are major concerns that degrade the performance of a typical face recognition system. To solve these problems, a visual pre-processor and extraction are required to localize and extract the face region from the background.

This research work is aimed at adapting face detection and recognition algorithms for identifying people in real time and offline time environment. Based on the literature survey in chapter two, the Viola-Jones algorithm is used for face detection purpose and its detection performance was tested using CMU, FEI, and Labeled Faces in the Wild (LFW) standard face databases. In addition, we compared the performance of principal component analysis (PCA) and linear discriminant analysis (LDA) algorithms with respect variation in facial expression, pose and illumination. We achieved a comparison of two algorithms by testing on ORL, FEI, and self-prepared databases.

1.2 Problem Statement

Advancement in electronic and computer technology are causing an explosive growth in the use of machines for processing information. In recent year, the word “computer vision” and” biometrics” are a buzz in the field of computer engineering and security. These become the most important research areas because of its usefulness in various applications such as access control, security system, secure networks, and access to storage archives, to identify participant at conferences and meetings [4, 5,30]. The increasing need for security in public and private sectors motivate us to conduct this work.

Most of thetraditionalmethod of personal identification requiresID card and physical inspection personal photograph with the real object, so biometrics method of identification is needed. There are several biometrics traits such as theface, fingerprints, finger geometry, hand geometry, hand veins, palm, iris, retina, ear, voice, gait, signature, and keystroke dynamicsthat capable of solving the traditional way of personal identification. However, face recognition offers several advantages over other biometric methods. Face recognition system has many potential applications that enable organizations to conduct a safe business transaction, to monitor day to day activity of the company, and achieve successful market competitive environment.

Although intensive research works have been done in face recognition area, still there is no a single method that satisfies 100% accuracy in all circumstances. In realistic application scenarios, a digital image that contains face can have a complex background which is difficult to differentiate from the face region. In addition, variation in pose, illumination, and facial expression are some of the major issues that degrade the accuracy of face detection and recognition system.

Pose variation

The performance of face recognizers is reduced significantly when pose variation is present in the testing image. Most of the training data used by face recognition systems are a frontal face of individuals. The problem of face recognition occurred when the system used a rotated testing image to confirm an individual identity. The frontal face has more information of individual than rotated or posed face. The faces in figure 1.1 have adifferent position which varies due to the angle between cameras and object being taken. The face taken from the same subject at different rotation angle may have large variation than faces taken from different subjects under control environment.

Figure 1.1 Pose Variation

Illumination variation

Illumination variation is another challenge that affects the performance of face recognition task. The light variation on the individual face causes a dramatic change in facial appearance. This is the most common problem that a typical face recognition system needed to address. If the change appears on the image caused by illumination is larger than the difference between individuals, face recognition system would not be able to recognize the input image.

Figure 1.2 Image with illumination variations

Facial expression

The facial expression of a person can produce large variation in facial appearance. The human feelings such as smiling face, closing eye, and surprising directly affect the apparent geometrical shape and position of the facial features. The influence variation in facial expression may be greater for geometry based algorithms than for holistic algorithms. Majority research works done before focus on small changes on the face surface. However, large variation such as laughing and shouting are still unsolved issues [4]. Figure 1.3 shows variation in facial expression of the same individual.

Figure 1.3 Facial expression variations

In this study,face recognition has been proposed in areal-time and offline environment. In order to address the problem,acascade classifier available inside OpenCV library and PCA and LDA algorithm have been used.

1.3 Research question

This study attempt to provide asolution for the following research equations:

- ✓ What are the face detection and recognition methods and which methods are best for face detection and recognition study?
- ✓ Can face recognition accuracy increase by applying preprocessing techniques?

1.4Research Objective

1.4.1 General Objective

The main objective of this study is to explore the possibility developing face recognition system using PCA and LDA algorithms and compare their performance with regard to various parameters.

1.4.2Specific Objective

To achieve the general objective, the following specific objectives are set.

- ✓ A comprehensive literature review is performed on face detection and recognition.

- ✓ Explore face detection and recognition development tools and techniquesthat are appropriate for this study.
- ✓ Collect sample face datasets from various sources and separate into training set, testing set, and perform feature extraction with the appropriate tools.
- ✓ Developing face detection andrecognition prototype using the selected methods.
- ✓ Evaluating the developed prototype using test datasets.
- ✓ Conduct a user evaluation to validate if the developed prototype is workable and can solve problems.
- ✓ Analyze results and forward conclusion and recommendations for further research in the area.

1.5Scope of Research

Nowaday, there are many available methods for face detection, feature extraction, and recognition. Considering all possible face detection and recognition methods is difficult with this limited time. Therefore, based on the literature survey in chapter two we select best methods among the available algorithms.Therefore, we consider the voila-jones method due to its high speed and robustness.We also consider PCA and LDA algorithms due to the reason that these methods are used to reduce the dimensionality of the image which minimize the memory storage and increase the efficiency of recognition.

The study also considersfour different publicly available image databases namely Labeled faces in the Wild (LFW), FEI face database, ORL, and CMUfaces. In addition, we have prepared our own image databasecollected from 40 volunteer individuals, and each individual has 5 face images in different facial expression, illumination and pose.

Due to thelimited time of the studyage variation is not considered in this study because variation in ageaffect the performance of the recognizer and need to perform a lot of tasks.

1.6 Significant of Research

As we discussed in the introductory part, a face recognition system is a hot research area because of its great potential and wide social need. There are many important issues that make face recognition so important for governments and companies from various sectors of industry.

After the completion of this thesis, it could allow giving concepts for users about face detection and recognition algorithms with better processing time, and memory utilization. And also it gives novel vision to concerned users towards better and modernized concept in face detection and recognition. On the same way the developed face detection and recognition system can be used to reduce the complexity of recognition in acomplex environment. It also increases human-computer interaction using facial features.

Furthermore, the study can also serve as a baseline reference and initiative to conduct further studies in the future.

1.7 Limitation of Research

There are many limitations we faced during conducting this study. Some of these limitations are due to lack of research experience, lack of material to support the study, and lack of regular training. There are also other limitations such camera resolution, computer processing speed and testing environment. Since our study is conducted using laptop built-in camera, the video resolution is very low, and this may affect the recognition rate of the algorithm. In addition, as the study is highly depend on image and video processing, the memory and CPU processing speed is another determinant factor that affect processing speed. Testing environment is also another limitation of this study. Due time limitation of the study, it is difficult to perform experimentation in all kind of environments.

1.8 Thesis Organization

Besides this chapter, the thesis contains five other chapters as seen in figure 1.4. Chapter two describes various biometric identification systems and compares their advantage with respect to performances, uniqueness, acceptability, and circumvention. The chapter also explains the theoretical backgrounds of face detection and recognition methods such as holistic, feature-based, image-based and template based approaches.Finally, a literature review of detection and recognition are studied in detail. Therefore, this can provide sufficient information for the reader to have a good understanding of how the system developed.

In chapter three, the research methodology of this research is described. The chapter explains about data sources, process modeling, and development tool and performance evaluation techniques.

The fourth chapter focuses on experimentation of face detection and recognition algorithms on various datasets. The performance of Viola and Jones method was checked on Labeled Faces in the Wild, FEI, and CMU MIT faces databases. In addition, we examine the performance of PCA and LDA algorithm on ORL, FEI, and self-prepared databases. Finally, we draw a comparative analysis of PCA and LDA based on the experimental result.

The final chapter discussions about the system and includes an area for further investigation and improvement. And finally, describe the conclusion.

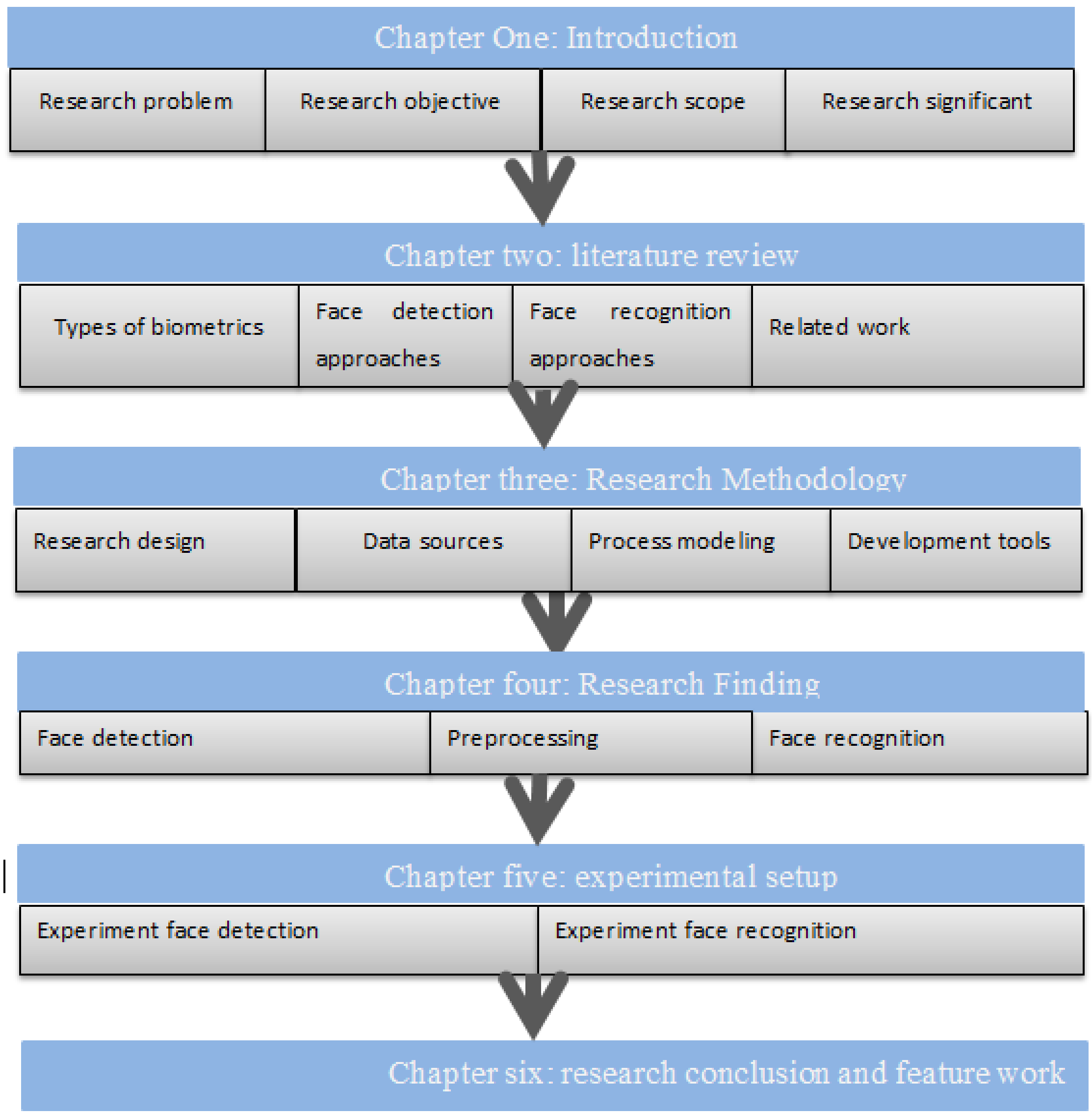


Figure 1.4thesis Structure

CHAPTER TWO

2. LITERATURE REVIEW

This chapter reviewssome common available biometric system that uses behavioral or physiological characteristics of a person and special attention was given to existing face recognition methods and tools that can be used to developan accurate and efficient system. The organization of this chapter as follows: section 2.1 focuses on theoretical background biometric followed by types of biometric systems that are commonly used for personal identification. Section 2.3 defines thebasic idea of face recognition systems. Section 2.4 deals withdigital image processing concepts and algorithms.Finally, section 2.5 explains related works on automatic face recognition.

2.1 Biometrics

The word biometrics is derived from twoGreek words "bio" and "metrics" where bio means "life" and metrics means "biological measurement". So the combination of these two words gives meaning "life measurement". Nowadays, the term biometrics is commonly usedinreal-time personal authentication and identification, securing various environments and other security-relatedworks [11, 12].

A number of biometric systems are available in themarket to verify or identifya person based on the behavioral or physiological characteristics such as face recognition; hand geometry, voice, and fingerprints are among the most common [2]. These technologies are more reliable compared with other methods such as RFID, and password because it eliminates manual input, identity card exchange, and time theft. Figure 2.1 shows alist of physiological and behavioral biometrics.

Physiological characteristicsdeal about thephysical appearance of thehuman body such as theface, finger, iris etc. whereas behavioral characteristics are related to the patterns of behavioral, natural aspects of thehuman being such as signature, voice,keystroke, ear, giant etc.eachbiometrics modality has its own strength and weakness.Therefore, choosing a typical biometric depends on different parameters such as performance, uniqueness, acceptability, Circumvention (Ease of use of a substitute), Collectability(how easily acquired the feature) [35][36]. Based on these parameters, various image-based biometrics has been intensively studied for various purposes. This section discussed some commonly used biometric method for choosing best method among them.

All biometrics systems can be operated in either verification or identification mode.The verification system is aimed to validate a person’s identity by comparing the captured biometric data with her/his template stored in adatabase (one-to-one matching). For example, Verification mode used in a computer access environment where a user inserts card such as ATM, but instead of entering a password, a simple touch of a finger.Whereas, identification system aims at identifying specific individual’s identityby comparing against every templatein the database (one-to-many matching).

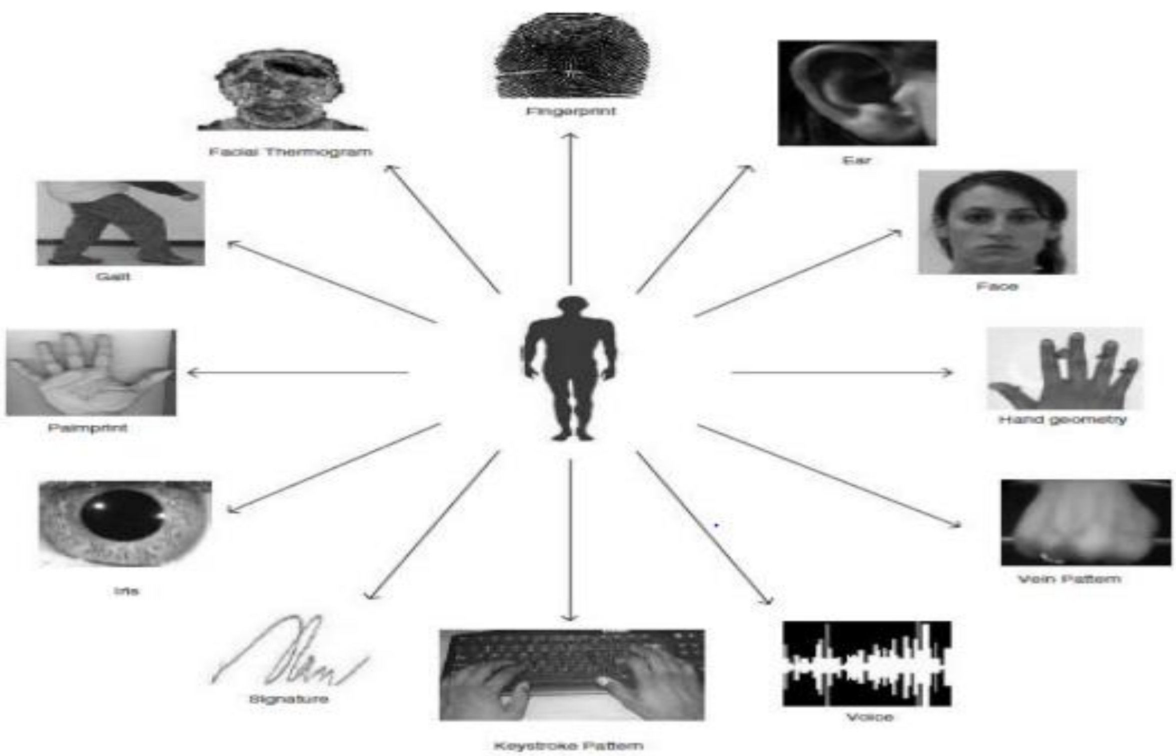


Figure 2.1 Biometric traits [2]

2.2 Face Detection

In a modern world, Face recognition is a revolutionary technology which enables to differentiate a legitimate userfrom illegitimate one [50].A typical face recognition system has face detection, face preprocessing, feature extraction and face recognition steps.

Face detection is a computer vision technology that determines the locations and sizes of human faces in images or videos regardless of the identity of that face [11]. It is an initial step in any face recognition system that able to detect facial features and ignores other image components, such as buildings, trees, and bodies [15]. The human face can be detected from online surveillance or offline image, where facial features such as eye, nose, mouth, cheek etc. are the main component to be detected. Ghani Honi [11] describes two basic steps for theimplemention of face detection system. The first step is localizing the facial features (e.g., eyes, eyebrows, nose, and mouth) which mean learning those part images where a face is present. After localizing the image, the system verifies that whether the image carries a face or not. But localizing and detecting a face from a large set of the image is a challenging and difficult task due to various factors in the research problem.

In last decade, there has been a great effort of research interests to cover several important aspects of face detection. More robust face detection methods have been presented, especially those using motion, color, and generalized information [12]. The introduction of statistics and neural network also play an important role to detect the face from cluttered scenes at different distances from the camera. Furthermore, there are some advanced feature extraction techniques such as deformable templates and active shape model which uses to locate and track facial features. Amir Faizi [12] and Kavi Dilip Pandya [17] presented two approaches to detect facial part in the given image i.e. feature-base and image-base approach. The feature-based approaches become more common since 1970 due to wide research interest in face detection method.

In this thesis, we use afeature-based algorithm for detection face region in a given image. Face features are important for face detection, localization, and tracking. The face detection algorithm checks the input image whether it contains human face or not if so, the face region will be enclosed with rectangle area. However, this process is not simple as we human being thinks. In general, there are two broad categories of facedetection methods as seen in figure 2.2 and each further subdivided into subcategories.

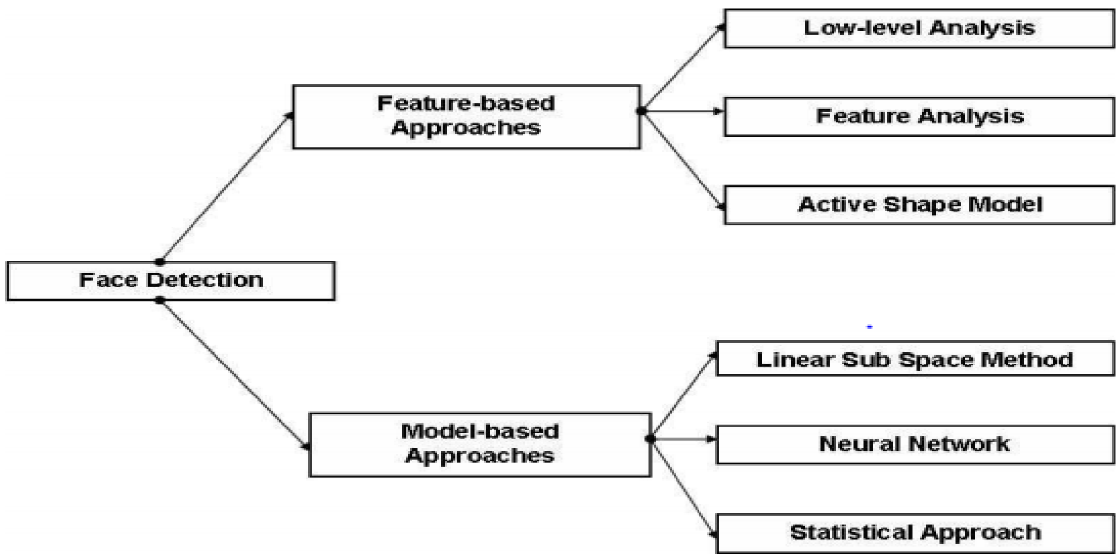


Figure 2.2 face detection approaches [12]

2.2.1 Feature-Based Approaches

It is real that all human being shares the same fundamental features but the only difference is the geometric relations between features structures [54]. With the of help feature-based approaches, the facial features such as eyes, nose, mouth, eyebrows, etc can be extracted and computed the relationship between facial features. As figure 2.2 shows, the feature-based approach further divided into three categories. The feature-based approach focuses on segmentation of facial features using pixel properties such as edge, Gray Scale, motion, and color information, and Feature Analysis [17, 16, 12].

The features generated using low-level analysis methods are not effective and robust due to the low-level nature and false region can also be treated as face region [18]. For example, in skin color model face detection, background objects of a similar color can be also detected as a face region. This classical problem can be solved by high-level feature analysis techniques such as feature searching and constellation. Feature searching and constellation are the more common high-level feature analysis technique among the literature surveyed. The feature searching strategy is based on finding the relative position of facial features while constellation is based on various face models.

2.2.1.1 Feature Searching

This technique deals with finding the most prominent facial features of a given image. Detecting the most important features allows for the existence of other less prominent features to be hypothesized using anthropometric measurements of face geometry [16, 12]. As many literature works indicate, Feature searching can be illustrated by a pair of eyes as the most general reference features due to its distinct side-by-side appearance. Other features include a main face axis, outline (top of the head) and body (below the head) also illustrated as the main component in this method. The algorithm by Paul Viola and Michael is a good example of features searching method. The algorithm works by finding individual facial features such as such as eyes, nose, and mouth and score the face candidates accordingly. Gabor Feature method also another features search method which uses to extract facial features from the original image on predefined fiducial points.

2.2.1.1.1 Viola Jones Method

In 2001, Viola and Jones proposed a technique for object detection which is capable of processing images and achieving a good result compared to the other approach [57]. Later it was extended by Lienhart and Maydt [19] in 2002. It is fast and robust face detection technique which is 15 times quicker than any technique at the time of release [11]. The method comprises three basic concepts that make possible to build a successful face detection system that can run in real-time [16]. First, the new image representation techniquescalled integral image which allows for very fast feature evaluation. The image intensity is not directly used for face detection but it uses achange of intensity values image.Second, thesimple and efficient classifier is built by selecting a small number of important features from a huge library of potential features using AdaBoost.The number of haar-likefeatures within the image scanner window is very large. A large number of features are excluded from thelearning process and focus on asmall set of features to ensure fast classification. The AdaBoost learning algorithm is used to select important features by limiting each weak classifier to depend on only a single feature. The final contribution is the cascade structure created by thecombination of more successful classifiers which dramatically increases the speed of the detector by giving more emphasis to themore promising region of an image. In this thesis, we have been used the Viola-jones algorithm to extract the face region from the entire image. More detail about theviola-jones algorithm is discussed in chapter 4.

2.2.1.1.2 Gabor Features

According to Peng Peng [75] image processing techniques mainly divided into two categories, a spatial domain analysis, and frequency domain analysis. In special domain analysis the image matrix is directly processed but in the case of the frequency domain approaches the image are transformed from the spatial domain to the frequency domain and then analyze the image feature. The special domain analysis is the most commonly used in image reinforcement, image reconstruction, and image compression. The Fourier transform uses to transfer signal from special domain to frequency domain. But this has a drawback to performing a local analysis. To solve the problem Dennis Gabor proposed a Gabor transform method that able to extract local information. It works by divide the signal into multiple intervals and then analyzes each interval using a Fourier transform. The Gabor transform also called Gabor wavelet which is used for image analysis because of their computational properties like spatial localization, and spatial frequency [79]. In the image, the Gabor wavelet can be applied by creating non-overlapping regions. The regions may have any type of shape especially rectangle grid is ideal due to simplicity. At the intersection point of the regions or grid points, the image will be decomposed into a set of wavelets with different direction and frequency. The set of wavelets at one junction point is known as feature vector or jet and the combination of jets are used to define an image. The number of wavelets in each jet and the number of grid points used to reduce the dimensionality of an image. Various studies proved that Gabor wavelet is essential for image decomposition and representation, but insensitive to illumination variation.

2.2.1.2Constellation Method

The methods stated in the above section rely extensively on heuristic information taken from various face images modeled under fixed conditions [12]. Therefore, these may not properly work for locating faces of various poses in a complex background. A more rigorous work has been done on face detection method to reduce this problem by grouping facial features in face-like constellations using more robust modeling methods such as statistical analysis [11, 12, 16]. The objectsare represented using some features and their spatial relations between them [80]. For instance, a human face can be represented as a collection of eyes, ears, nose, mouth, hair and skin, with nose lies between eyes and mouth. Therefore the generic object is modeled as constellations of features or constellation model. Each feature or parts has its own appearance and shape properties, and these features are tightly or loosely tied together by class-specific spatial configuration constraints. Various types of face constellations have been presented in [12, 1]. Wei-Lu Chao [13] built a statistical shape model facialdetector using multi-orientation and multi-scale Gaussian derivative filters. They select facial features such as two eyes, two nostrils, and nose/lip junction and produce a prototype filter response for each of them. The multivariate-Gaussian distribution is used to represent the distribution of the mutual distances among each facial feature. Their experiment achieves 86% accuracy rate for the cluttered image. Another research by Burly et al [81] proposed a face localization system by combining the local detectors with a statistical model of the spatial arrangement of facial features to produce a good performance [12]. Like Lun Chao the multi-orientation, multi-scale Gaussian derivative filters are used to identify candidate locations of features. The results of the local detectors are considered as candidate feature locations and the constellations are form from these. The constellations are classified based on the probability that the shape variables correspond to a face versus an alternative model. The constellation may not be complete due to missing some true features. The problems such as translation, rotation, and scale and missed features are handled by mapping to a set of shape variables [12, 81].

2.2.2 Model-Based approaches

2.2.2.1 Active Shape Model (ASM)

Unlike the other feature-based methods described in section 2.2.1, the Active shape models concentrate on complex non-rigid features like actual physical and higher level appearance of features [11, 12]. It is themost common modelused to locate landmark points that define the shape of any statistically modeled object in an image and the shape of an object is iteratively deform to fit the object in a new image[81,82]. The set of facial features such as eyes, lips, nose, mouth, and eyebrows are demarcatedwithin landmark points. These can be described asa set of distinguishable points present in most of the images under consideration. For instance nose, eyes etc can be represented as below fig. 2.3.

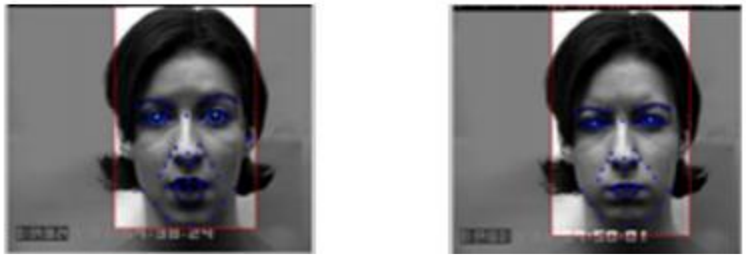


Figure 2.3 ASM Facial Features [82]

The set of landmarks forms a shape and each shape represented as vectors of (x, y)coordinates points. The shape of theobject can be defined as a set of $\boldsymbol{n}$ point in the $\boldsymbol{x}$dimensions [84].

$$\mathrm{x} = (\mathrm{x}_1, \mathrm{y}_1, \mathrm{x}_2, \mathrm{y}_2 \dots \dots \mathrm{x}_n \mathrm{y}_n)^{\mathrm{T}} \dots \dots \dots (2.1)$$

As figure 2.3 shows, the best landmark points are being chosen by finding the same points in another image. These points are situated at the place of the object boundaries and it resembles with most accuracy the shape of the faces.The ASM is important to build a model which enable to create new shapes and to synthesizeshapes similar to those in a training set. The training set derives from hand annotation, but there may be some automatic landmark systems [84].Amir Faiz 2008 [12] and Ghani Honi 2014 [11] describe three categories of ASM. The first category called snakewhich was first introduced by Kass et al in 1987 [56]. Later Yuille et al [66] proposed a deformable templates method to take into account the a priori of facial features and to better the performance of snakes [11, 12]. While the third category is a more flexible model named smart snakes andpoint distribution model (PDM) which was introduced by Cootes et al [16, 12, 11]. This provides more efficient interpretation of the human face by using a set of labeled points that are only allowed to vary to certain shapes according to a training procedure [56].

2.2.2.2 Image-Based Approaches

As we have been shown in the previous sections, the feature based approaches arerelying on explicit face features. The accuracy of the system can be affected by unpredictable face appearance and other environmental factors. Even if more attempts have been made to improve the performance of the feature based methods, there are still limited to head and shoulder and quasi-frontal faces. Therefore, it needs to use methods that can work in more problematic scenarios such as detecting multiple faces with clutter-intensive backgrounds. These conditions have inspired the researchers in this area to treat face detection problem as face and pattern recognition problems. Unlike the feature-based approach that relies onfacial features, the image-based methodsusepredefined face patterns or templatesto determine whether the input image hasa face or not.The training algorithm classifies the image region into face and non-face classes. Most Image-basedmethodsdepend on multiple resolution windows scanning for faces detection [2].The window scanning algorithm is essential for systematically search the possible face locations from the inputimage;however, there are some variations in theimplementation of these algorithms in most of allimage-basedsystems [56].Each method may vary the size of the scanning window, the sub-sampling rate, the step size, and the number of iterations which areneeded for a computationally efficient system. This approach divided intolinear subspace model, neural network, and statistical approaches [12, 2].

2.2.2.3Neural Network

Neural network method is becoming much more popular for face recognition, face detection, and autonomous robot driving. Its popularity is due to the adaptive learning, self-organizing, real-time operation, and fault tolerance via redundancy information coding [2]. The Basic idea of the neural network was started when researchers trying to understand how the biological neural networks processing information. The neural network includes various nodes connected together to form a network. The network should be adopted by some methods to generate the expected result. Early effort on neural networks has dated back the early of the 1970s, where high processing speed techniques were used to solve complex problems. As other techniques, it has also some limitations such as slow for a complex problem, susceptible to noise, and highly dependent on training set [86], however, it can be reduced through careful design.

The Multiple Layer Perceptrons (MLPs) is an early neural network method implemented for face detection system, and it generates an encouraging result on fairly simple datasets [86]. Later in 1998, Rowley et al [85] presented a more advanced neural network approach that operates on a large and visually complex dataset. The system is based on retinal connected neural network (RCNN) that examines small windows of an image to decide whether each window contains a face [86]. To minimize the number of false positive, they use several networks and every network is trained in the same manner, but with random generated initial weights, and permutations of the order of presentation of the scenery images. Their output combined using various arbitration methods to produce the final decision. However, face detection training using neural network method is challenging task due to the difficulty of characterizing the non-face image.

2.2.2.4Statistical Approaches

Other than the linear subspace and neural network techniques, there are several statistical face detection techniques that deal with nonlinear subspaces (kernel-PCA and kernel-LDA), Support Vector Machine (SVM) [89], Bayes' decision rule [56], and transformation such as DCT, HMM and Fourier Transform [89]. Statistics approaches attract the interest of many researchers in the area of face detection and recognition. The method is based on a statistical feature of a face acquired through learning and use the acquired knowledge to classify the face [75]. A few statistical techniques outlined in this section are the Support Vector Machine (SVM) classifier and Bayes' decision rule. In face detection system, train or learn a rule that identifies a class of objects from a class of non-objects is challenging task.

Schneiderman and Kanade [70] design a face detection system based on Statistical model and probabilistic learning. They statistically represent the appearance of an object and the rest of the world. To construct the statistical model, they adopt multiple histograms where each histogram represents the statistical behavior (attributes) of a different group of quantized wavelet coefficients. But histogram can only be used with a relatively small number of discrete values to describe appearance. So to deal with object detection, they extract multiple attributes from the image and compute their histograms separately. The overall model for Bayes' decision rule is described as the ratio of the two probabilities (Eq. 3).

$$\frac{\mathrm{P(Image/object)}}{\mathrm{P(image/non-object)}} > \frac{\mathrm{P(non-object)}}{\mathrm{P(object)}} = \lambda \ \ldots\ldots (3)$$

If the ratio of the left side is greater than the right side (Eq.3), therefore it is decided that an object (a face) is present and object is not present if the condition is not satisfied. Using the Bayesian approach (maximum likelihood), one can choose the most likely class of a new data point [90]. There are two advantages of writing the Bayes' decision rule as a likelihood ratio (Eq.3). First, it is simple to collect statistics for two probability functions, P (image | object) and P (image | non-object) [56] than directly collect statistics for the posterior probability function. Second, by expressing the Bayes decision rule as above equation, the result of the prior probabilities can be afactor out and combine them into a scalar threshold, λ. Then the algorithm can be applied to different settings by changing the threshold.

Stanley Michael Bileschi (2003) describe two density based classifiers and Support Vector Machine (SVM) for face detection. Like Kanade et al [91], they use two different density estimation classifiers. The probability of positive data (face) is being calculated by finding the mean and covariance matrix of Gaussian distribution, but the probability of negative data is computed from a uniform distribution, where every distribution x is equally probable.

2.3Machine Based Face Recognition

According [68] the ability of humans to recognize faces provides an implicit benchmark for designing an effective face recognition system. Chellappa et al (2009) presented in his paper, early efforts on pattern classification techniques have dated back 1970's where measurements between features in faces or face profiles, were used. After 10 years, the work on face recognition becomes more interesting than the previous [66]. At the early 1990's research interest on face recognition has been grown extremely and many new methods were emerged to increase the performance of the recognizer. This is due to the reason that:

- The availability of high-quality hardware devices such as camera
- The extensive need of highly secured application
- The studies on neural network classifiers with emphasis on real-time computation and adaptation [66]

Face recognition touches many research areas such as computer vision, machine learning, and neural network [11]. Untilthis day, a number of methods have been introduced in literature for matching the face acquired from image or video camera. Figure 2.4 shows three type of face recognition methods. The analyticapproach is based on the analytic techniques, which use facial features, geometric-based, and template-based methods. The second method is based on holistic approach, which uses the information derived from the whole face pattern includes PCA, LDA, and ICA. Whereas the third category, hybrid approach combines both local and global features, this method produces a complete representation of facial images [11][2][66].

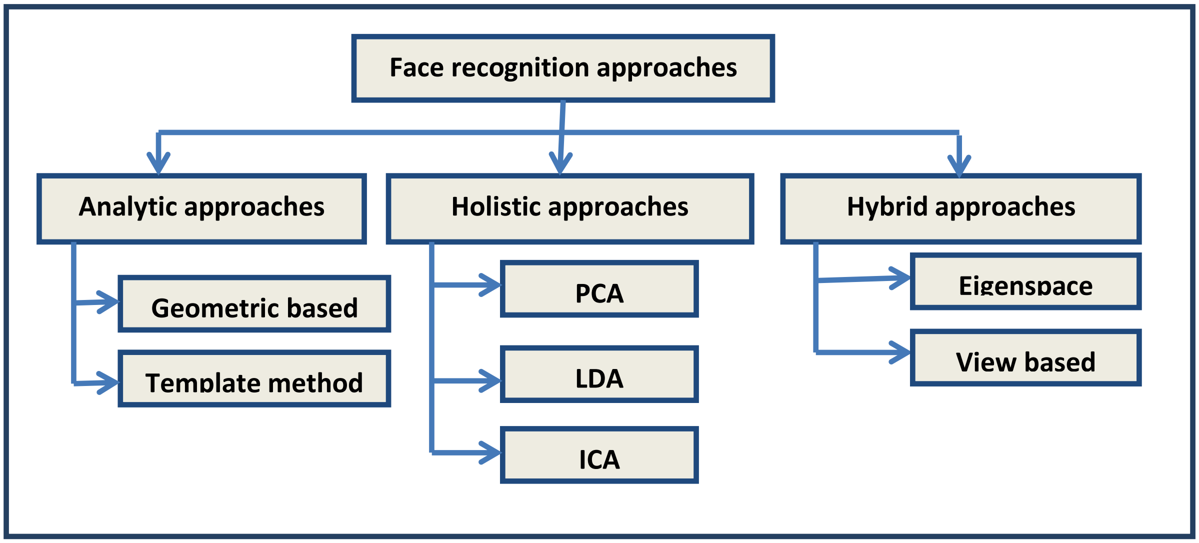


Figure 2.4 classification face recognition techniques

2.4 Analytical Approaches

Analytics approaches presented in [66],various features such as distance, theangle between facial points, and shape facial features are extracted for face recognition.Analytics approach also further divided into thetemplate and geometrical feature methods as shown in figure 2.4 and it focus on extracting local features such as eye, nose, mouth, and hair for identifying face of an individuals, while in template method, the facial features are used to match with facial point templates such as eyes, nose, and mouth etc, where the similarity scores of each facial feature are simply added into a global score for face recognition [89].The major benefit of this methodis to design a flexible system that effectively works with defamation of key feature points.

2.4.1. Geometric Local Feature Method

The geometric method is based on extracting or measuring distinct facial features and computes the distance between those facial points. It is different from feature-based method because it constructs agraph using the facial features of each subject [66]. Standard statistical pattern recognition methods are then used to match faces using these measurements [14]. Most of the early automated face recognition systems were based on geometric based. The first effort made to develop automatic recognition of face using avector of geometric features was by Kanade et al (1973) where a set of 16 features were computed using robust face detector. The Kanade system achieves 75% correct recognition rate on a database of 20 different peoples using 2 images per person one for training and 1 for testing. The intra and extra class variations are among the factors that affect the effectiveness of the system.

Anotherresearch by Brunelli and Poggio[70] compare two different algorithms. The first experiment was based on the computational set of geometric features such as nose width and length, mouth position and chins shape, while the second experiment used template matching technique and the overall experiment achieve 90% and 100 % for both geometric features and template matching respectively.

Ladis et al [69] proposed an object recognition system based on the dynamic link architecture, which is an extension of theclassical artificial neural network. Objects were represented using spares graph whose vertex were labeled by a multi-resolution description in terms of a local power spectrum, and whose edges were labeled by geometrical distance vectors. In this technique, a set of feature vector was formed over a dense grid of image points based on Gabor-type wavelets. The magnitude of Gabor wavelet coefficients was used for matching and recognition. During recognition of a face from an image, every graph in the model was matched against the image separately and scored good result against 87 images with different facial expressions. However, the matching process was time-consuming, taking 25 seconds to compare an image with 87 stored images.Anotherresearch which was presented by Starovoitov et al [71] compares geometric, elastic matching and neural networks method for face recognition. The geometric method was tested on 70 images of 12 persons collected from Olivetti Research Laboratory (ORL) face database collected and achieved 98.5% recognition rate. While elastic matching and neural networks methods were achieved 92.5%, 94% recognition rate.

More recently, Sonu Dhall and Poonam Sethi [72] presented a survey on geometric and appearance feature analysis for facial expression recognition. They evaluated thefacial expression on Local Binary Patterns (LBP) three orthogonal planes, Pyramid of Histogram of Gradients, and a geometrical feature based on thedistance between fiducial points for person-independent facial expression recognition. A support vector machine (SVM) classifier was used for face detection tasks. They train and test the classifier using 70 and 30 subjects respectively and scores satisfactory result.Moreover, the face recognition methods (LBP-TOP) achieved 45.45% accuracy for Cohn-Kanade database which is quite more than that for geometric points (23.14%).

2.4.2 Template Method

As Unsang Park [50] explained, template method is based on finding similarity between the input image and the template image stored in thedatabase. It is related to holistic methods which attempt to represent the whole face appearance, and use cross-correlation between theinput image and stored templates of thewhole face features to determine the presence of the face. The face features can be defined individually as eyes, face contour, nose, mouth, and edge model. These methods are important to deal with frontal face.Ion Marqu´es [78] presented the silhouette face template and the relation between brightness and darkness region to represent face template.Anshita Agrawal [77] also describes adifferent form of template matching; for instance,a testing image can be represented as atwo-dimensional array of intensity values and compared using a suitable metric, such as the Euclidean distance, with a single template representing the whole face [66]. But some template matching methods may use more than one face template from adifferent viewpoint to represent each image.This method is simple to implement and achieve agood result but it has time computational complexity problem.

2.5 Holistic Approaches

Holistic approaches utilize the entire face region in the detected image to perform face recognition. The most relevant information that describes a face is derived from the whole face image [2], and the information used to uniquely identify individuals. This approach very important because designing a model for thegeometric based method is difficult due to thelarge variability of face appearances like pose and light variance, while in template method it is difficult to deal with anon-frontal view. There are several well-known holistic methods available like principal component analysis (PCA), linear discriminating analysis (LDA) and independent component analysis (ICI) for face recognition [2][60]. Sirovich and Kirby [56] use PCA to develop the eigenface method for face recognition and representation. In the eigenface method, the whole face pattern is converted to feature vector and the eigenfaces are computed from a set of training images. PCA mainly focus on reducing the high dimensionality of training sets to lower dimensionality by preserving the key information contained in the dataset. Currently, this method has been implemented by many researchers such as [11, 2, 56, 66] and obtained high recognition accuracy under various facial expression variance using ORL, YALE, and FERNET databases.

In 1997 another holistic method called fisher-face has been proposed by Belhumeur et al [45] for face recognition.Similar to eigenface method that uses dimension reduction technique (PCA), the fisher-face method uses LDA to find the subspace within which a set a sample face images can be represented[93]. The LDAdescribesa projection that minimizes the scatter (variance) between images of the same class and maximizes the scatter between different class images (images of different individuals).Even though LDA is a reliable technique for extracting the discriminative features of face for recognition purpose, it encounters two major problems during applied for face classification.First, the scatter matrix of the LDA in the same class and different classes cannot be precisely computed due to the dimension used to classify face images are much higher than the number of sample face images, and thesecond problem is encountered due to small training sample set size [14]. To solve such problem, LinLin Shen [89] appliesdimension reduction techniques (PCA) to reduce the feature dimension before LDA projection.

A comparison analysis between LDA and PCA face recognition techniques was conducted by [11] on YALE face database images with a different number of images size and achieve better result. Sejnowski et al [89] proposed independent component analysis (ICA) method for face recognition and achieve agood result.

2.6 Hybrid Approach

Hybrid Approach uses a combination both holistic and analytic Based Approaches [28]. These methods have the potential to offer better performance than individual holistic or local methods since a complete information could utilize [2]. In hybrid based face recognition, all individual faceshares the same basic features arranged in some common pattern and each individual face can be differentiated by analyzing a face component and holistic information. Both the holistic and analytic face recognition approaches have their own strength and weakness, therefore by combining these approaches; a high-performance face recognition system can be achieved. For example, the analytical methods have thedrawback of high dimensionality, but it is robust against the problems of illumination, change of expression which represents major challenges holistic methods. On the other hands, the holistic methods are essential to reduce the dimensionality of the dataset. Therefore, combining these two approaches produce a face recognition system with minimum environment constraint and high recognition performance.

An early work by Pentland et al [74]extended the eigenface technique.They utilized eigenfeatures features such as Eigeneyes, Eigennoses and Eigenmouths [89]. The experimental result indicates that the result of the eigenfeatures method is better than eigenface method but the computational time is still unsolved issue.Another hybrid based research work by Andrew D. Back [96] combines a local image sampling, a self-organizing map (SOM), and a convolutional neural network. The self-organizing map used for projection of the local image sample representation into quantized low dimensional space where the inputs that are nearby in the original space are also nearby in the output space, furthermore it can be used for dimension reduction and minimize changes. While, the convolutional neural networkused to reduce minor changes such as translation, rotation, scale, and deformation.

Pallabi Parveen and BhavaniThuraisingham [94] developeda near real-time face recognition by combining both holistic and analytic approaches. They used PCA to reduce the dimensionality of the data set and facilitate the accuracy of real-time face recognition.To increase the accuracy of the classifier, they implement a hybrid model that combines different classification techniques i.e. ANN and LDA. Both LDA and ANN are used for predicting data, but LDA only used with seen data. Furthermore, the LDA may not work with high dimensional data set, which means that the performance of the recognizer may be degraded. So the PCA is applied for feature reduction and select essential features, then these features are used to train and test the LDA classifier. The effectiveness of the hybrid model was evaluated by comparing the experimental result obtained from the data set using ANN and LDA. By combining the LDA and ANN, they achieve 91.2% accuracy rate.

Another research work presented by N. Paves□ic□ [95] based on trace transform and the novel kernel partial-least-squares discriminant analysis (KPA). The hybrid approach ortrace kernel partial-least-squares discriminant analysis (TKPA) uses a setof fifteen trace functional to derive robust and discriminative facial features and then applies the KPA method to reduce their dimensionality. The performance of the hybrid approach was tested on XM2VTS database, and achieved 1.25% false rejection rate (FRR) and 2.11% false acceptance rate (FAR).

More recently, Sadi Vural [4] proposed a novel face extraction and classification methodology for face recognition in uncontrolled environments. They developed a new image preprocessing technique called “Ayofa-filter” for face recognition, and the Gaussian decomposition technique was used for image normalization. To perform face recognition, they develop hybrid feature extraction methodthat uses spatial face filters (SFF) for obtaining high accuracy. The SFF is implemented using spatial Gaussian Bessel mixtures (SGBM) in which the SGBM combines Gabor filters and Bessel function. Since the Gabor filters are not adequate to extract face features, they combine both Gabor filters and Bessel function to produce more complicated filters, and then the SGBM is applied on the whole face surface, and the facial features are extracted the and analyzed using hierarchical nonlinear PCA (H-NPCA). The overall approaches were tested on images and video acquired from major face recognition databases such as FRGC, CMU-PIE, and Extended Yale-DB databases and achieve high performance.

2.7Related Work

In this section, we introduce related works on face recognition. Reviewing related to the subject area of face recognition has a vital role in choosing appropriate mechanisms tosolve theproblem and enhance the performance of the recognition system.

In the last decade, many image processing algorithms were studied and experimented for face recognition. Holistic methods such as PCA, LDA, and ICA are widely used for automatic feature extraction and recognition. Gabor is feature-based approach and AAM is hybrid approach have solved some issues of face recognition. However, the processing speed is still challenging when applying for real-time applications.

The research of face detection and recognition in offline environment has achieved aremarkable result. Some researchers such as viola-jones proposed machine learning algorithm for detecting aface. yogesh in 2012 uses color information to locate ahuman face in acomplex environment. In 1902, Karl Pearson first proposed PCA to reduce the dimensionality of data sets, and later used by Sirovich and Kirby 1980 [56] to efficiently represent a human face. Turk and Pentland [74] propose eigenface technique for developing real-time automated face recognition systems. Although the approach was constrained by environmental factors, it plays a prominent role in advancing the development of automated face recognition technologies.

Belhumeur et al [45] propose LDA method to solve singularity problem of PCA. Because the author argues that PCA method is effective for an individual with a single image, but when multiple images per person are present, it does not minimize the total scatter matrix within the same class. By applying LDA the total class matrix within the same class will be minimized.

In 2013, Gyasi Silas Baah [66] utilized principal component analysis for reducing the dimensionality of the data set from initial 36000x3040 to 2279x2279. They used an eigenface as a main feature extraction technique and achieved 98.8158% accuracy with an error rate of 1.842%. Even though the author describes the possibility of detecting facial features such as eyes and the mouth, it is not clear that which face detection method they actually use.

In 2014, WEI CUI [25] proposed a new face recognition schema in a complex environment. They split the whole system into three different phases. The first phase deals with moving object removal. They employed frame differencing techniques to remove moving objects such as pedestrians, cars and other objects. The frame differencing techniqueused to separate the static (nonmoving) and dynamic (moving) objects. The second phase is a face detection which is technology that utilizes OpenCV cascade classifier to locate facial features such as eye, nose, and mouth based on viola and Jones method. The final phase utilizes PCA for face recognition purpose. However, the author utilizes small number of images to train the face detection and recognition methods. In addition, the author only targeted for people closest to the camera or stationery.

Another research by Dhafer Ghani Honi [11] conducts a comparative study of PCA and LDA face recognition methods. The researcher evaluated each method on three datasets of face images with equal working conditions. Time and accuracy were used as evaluation parameter for the study. The overall experiment showed that LDA is much better than PCA in all face set with various disturbances when the database is large,But PCA generated abetter result as the database decrease.Even though, the author achieves better result, various preprocessing techniques are not considered.

More recently, Justin Nicholas Worsey [98] developed a face recognition system based on four fundamental face recognition pipelines.The first stage deals with image data filtering and preparation where the face regions are detected in the detection stage and align at the alignment stage, while in the second stage deals with feature extraction and classification. They used Viola-jones face detection algorithm to detect face region from the input image before passing the entire image to the database for recognition purpose is given in see section 4.6.1 and then the result of the detection phase is aligned using Active Shape Modeling (ASM) to fit a face model to the region of interest.

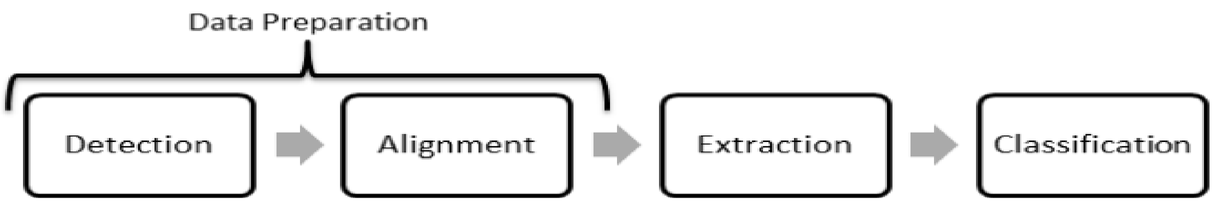


Figure 2.5 Face Recognition Pipelines [12]

In addition, Justin Nicholas Worsey employed Eigenfaces method for extracting variance in theimage, Scale Invariant Feature Transform (SIFT) for extracting and clustering the image using Differences of Gaussians filtering; and Local Binary Pattern (LBP) techniques for transforming the image based on the contrast of pixel intensities. They also explicitly stated two ways of employing face recognition algorithms namely using single pass algorithm and multi-pass algorithm. the overall experiment was evaluated using LBP, CS-LBP, SIFT, Eigenfaces, Eigen LBP and Eigen CS-LBP face recognition algorithm in 23 serious lecture class and achieved agood result. But,the researcher didn’t explicitly show when the recognition occurs (in real-time or not) since the images for theexperiment was taken by the lecture using his/her mobile phone. In addition, this typical system is designed for student attendance.

In general, all the reviewed related works are done onface detection and recognition algorithms. Each research work contributes more or less to maximize the efficiency and accuracy of the algorithm. Most of the of these research works are focus on offline environment, however, face detection and recognition in real time environment is more challenging due to various reasons described in the statement of the problem section. In addition, image resolution is another factor that degrades the performance of the detector and recognizer.

CHAPTER THREE

3. Research Methodology

Research methodology is the way to systematically solve the research problem. It is ascientific way of understanding the problem domain and provides asolution in a scientific way. It also deals withvarious steps for studying the research problem along with the logic behind the research problem.

The main purpose of this chapter is to develop knowledge based on the state of the problem and develop a solution by adopting several steps which are necessary to do the intended function of the research work. Figure 3.1 shows the applied methodology of the research work.

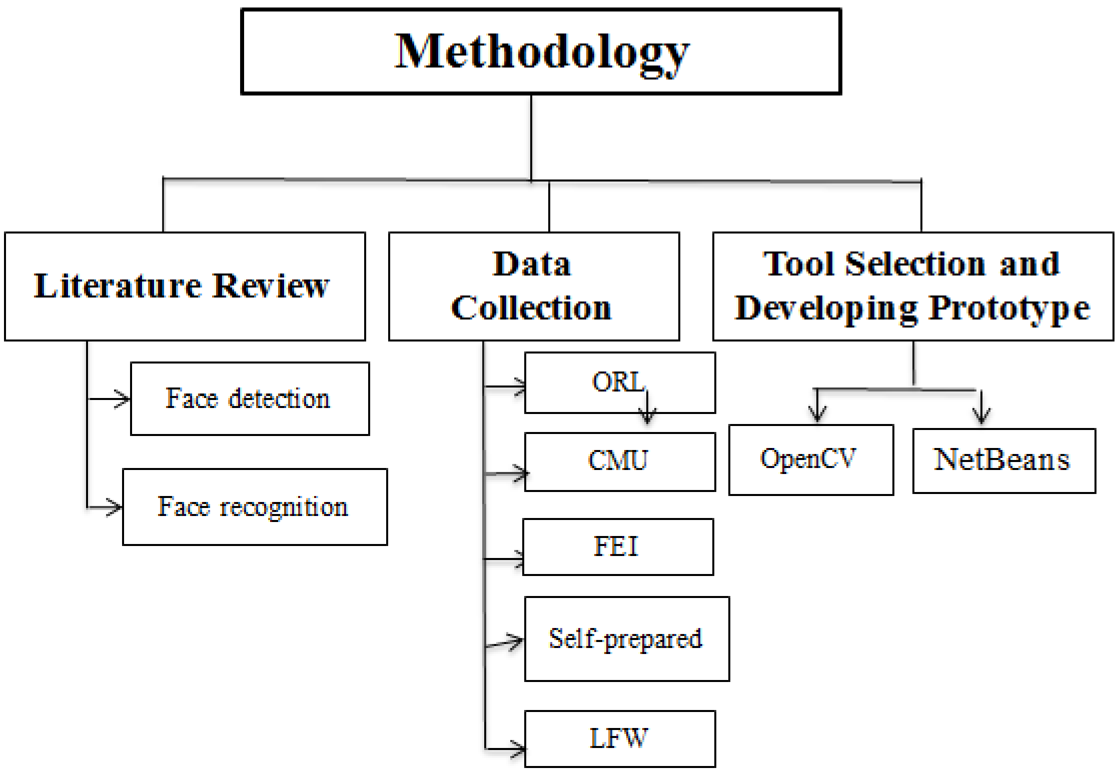


Figure 3.1 Research Methodology

In general, various steps are required to conduct this research as shown in figure 3.1. First, we review different research papers related to our study for identifying research problems described in section 1.2. Second, we collect large amounts of data in order to generate reliable result for both face detection and recognition.Moreover, appropriate tools such as OpenCV, and NetBeans IDE were selected to develop the prototype.We also train the algorithm and test using a set of positive and negative test images and finally evaluate the performance of the method based on serious of tests result.

3.1 Literature Review

Reviewing related works are important to share their idea in identifying what has been done and needs to be done in the area. Literature survey in the area of face detection and recognition has been reviewed from various sources including books, journal articles, conference papers, magazines, and the Internet. This helps as to investigate the fundamental principles of various approaches, techniques, algorithms, and tools that would be best for this research. The viola and Jones method, principal component analysis, linear discriminant analyses face recognition methods were part of the review. In addition, to understand how the OpenCV it works, various OpenCV books and professionals were consulted. Finally, various documents about face datasets were assessed so as to have a good understanding on choosing best face datasets for this study.

3.2 Research Design

A researchdesign is a set of methods and procedures used in collecting and analyzing measurement the variables specified in the research problem.Getting the right research design is the first step towards organizing a research which is more likely to be a good research. According toBurns and Grove (2003), a research design is a blueprint for conducting a study with maximum control over factors that may interfere with the validity of the findings. A research design also defined as a plan that describes how, when and where data are to be collected and analyzed. This helps us to carefully consider the research and to plan the way in which they will approach the research.It also plays an important role to integrate the different components of the study in a coherent and logical way.

In this thesis we applied different methods starting from problem identification; define the objectives for a solution, Design and prototype development, and testing and evaluation the performance.

I. Problem Identification

Problem identification is the first step in the research design processwith a clearly articulated problem is widely recognized.In this study we start byclearly defining research problem and justify the value of a solution by conducting rigorous analysis of the literature on face detection and recognition. Based on the problem definition, we atomize the problem conceptually to capture its complexity for developing the face recognition system that can effectively provide a solution.

II. Defining objectives for a solution

Depending on the knowledge of the state of problems we infer the objectives of a solution and knowledge of what is possible with the face detection and recognition environment.The qualitative objectives are used, which described how a proposed algorithm is expected in order to support solutions to the problems.

III. Designing and developing prototype

Design and Development prototype is often focused on a specific product, or program. In this study, weexamine the entire design and development process from analyses to evaluation.In general, the process entails: building a face recognition model, and building a prototype for testing and evaluation.

The Viola-jones algorithm was used to build the face detection system. It is a powerful technique capable of fast, robust, anddetect face from a digital image.

Furthermore, two popular holistic methods: PCA and LDA are used for face recognition purpose. PCA and LDA algorithms are very popular due to their simplicity and easy to implement, fast computational time, and simplicity to work in real-time environment.

For developing the prototype, the OpenCV library with NetBeans IDE is used. The prototype has been built entirely in the Java programming language.

IV. Testing and Evaluation of Performance

Performance evaluation is an important part of face detection and recognition system. First, a set of images datasets are collected from various sources, and then separated into training and testing sets. The system was initially trained using images captured from different individuals and faces from available databases were labeled and separated into the training set as the experiment proceeded. Each testing set is assessed against the training dataset. The set of testing results such as negative identification rate, positive identification rate, and negative rejection rate were recorded through manual inspection. Negative face identification can be defined as the number of misrecognized faces out of all tested face images. The identification rate can be defined using formula below.

$$MRR = \frac{\text{TMRF}}{TNF} \tag{3.1}$$

$$Accuracy = \frac{\text{PTR}}{TNF} \tag{3.2}$$

Where MRR is a miss recognition rate, TMRF is the total number misrecognized faces per subject, TNF total number of faces in the testing set, and TPR is the total number of positively recognized faces.All these variables and calculations are necessary to see how the system effective in practical scenario.

As we describe in section above, this study includes five main parts: research motivation, literature review, research methodology, experiment, results and discussion, and conclusion.Three experimental methods were implemented in this study as shown in figure 3.2. The first experimental method is image preprocessing, second is face detection and finally face recognition.

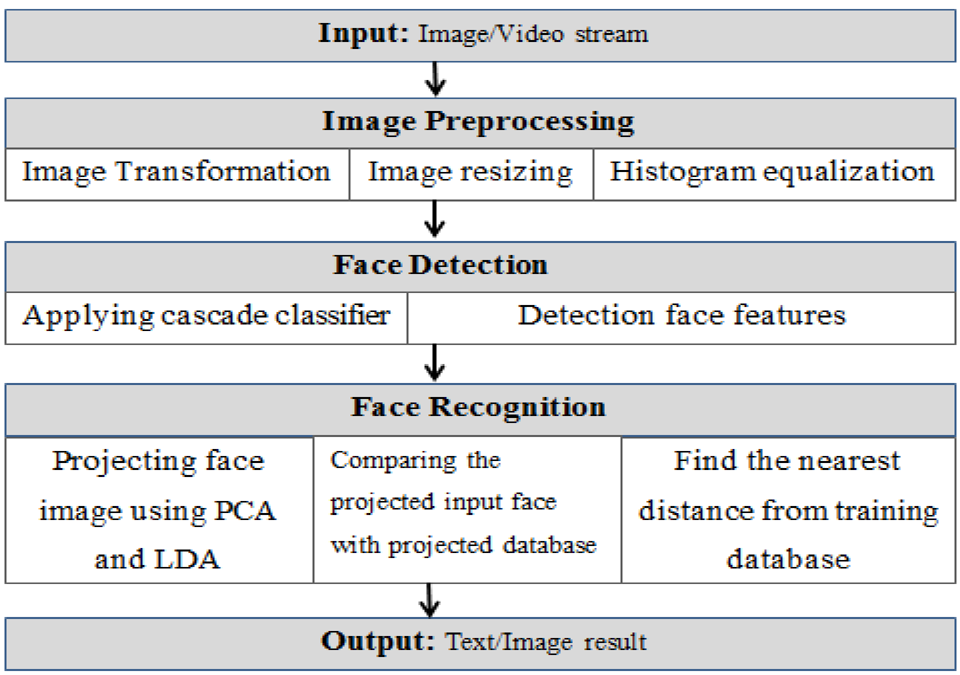


Figure 3.2 face recognition research workflow

In face detection stage, we used the OpenCV cascade classifier for detecting the face of a person. The haar cascaded features available inside the OpenCV library were trained based on the viola-jones algorithm which is described in section 4.4. The OpenCV library is not only used for detecting a face, but also it detects a humanbody and movement.

In this thesis, frontal face classifier was used to evaluate whether the frontal face detected or not. Some of the OpenCV cascade classifier used for face detection listed below

Table 3.1 OpenCV cascade classifier

Face features	**Haar feature based cascade classifier**	**Description**
Frontal face	haarcascade_frontalface_alt.xml	Stump-based gentle AdaBoost frontal face detector
Frontal face	haarcascade_frontalface_alt_tree.xml	Stump-based gentle AdaBoost frontal face detector. This detector uses tree stage classifier instead of cascade
Frontal face	haarcascade_frontalface_alt2.xml	Tree based gentle AdaBoost frontal face detector.
Frontal face	haarcascade_frontalface_default.xml	Stumped-based discrete AdaBoost frontal face detector
Full body	haarcascade_fullbody.xml	Haar based detector for pedestrian detection.
Eye	haarcascade_eye.xml	Frontal eye detector
Eye with glass	haarcascade_eye_tree_eyeglasses.xml	Tree-based front eye detector with better handling eyeglass
Mouth	Haarcascade_mcs_mouth.xml	Mouth detector computed with 7000 positive samples
Nose	Haarcascade_mcs_nose.xml	Nose detector computed with 7000 positive samples

3.3 Data Sources

In order to build high-performance face detection and recognition model, we should be gathereda large amount of data from various sources. The collected data should be sufficiently large, consisting of positive and negativeface samples taken from different individuals under different environmental conditions. Collecting such datasets is the primary task of this thesis.

In this study, majority data required for theexperimentare collected from well-known public image databases available on the internet. These databases are prepared under various environmental conditions. The next sections clearly discuss some free available image databases used in this study.

3.2.1 Labeled Faces in the Wild (LFW) Database

The Labeled Faces in the Wild database (http://vis-www.cs.umass.edu/lfw) contains more than 2339 image of face collected from the web. Each individual face has labeled with the name of the person in the picture. In this experiment, we collect 218 distinct labeled directories and each labeled contains one or more image of the same person as shown below. Some image contains more than one face of different individuals, but faces other than the targeted individuals are considered as background faces.

a) sample images from Labeled Faces In Wild (LFW) database

Figure 3.3 sample images from Labeled Face in Wild database

The database contains a large set of images with large variations seen in everyday life. The variation including pose, lighting, expression, background, race, ethnicity, age, gender, clothing, hairstyles, camera quality, color saturation, focus, and other parameters [22]. Most of the imagesare colored with 250 by 250 pixel JPEG images, but few of them are Grayscale images.

See link http://vis-www.cs.umass.edu/lfw

In this experiment, all images are evaluated using the viola-jones method and false positive and false negative face detections were analysis manually.

3.2.2 CMU Face Database

CMU MIT is another well-known standard face database considered in our experiment. Itcontains images from western peoples and few from Africa and Asia. The database contains a set of 202 images separated in four different directories known as a test, rotated, low test and new test. The images were captured under varying facial expressions, race, rotation, and illuminations. The database includes both positive (image with faces) and negative (image without faces) test images. All images are Grayscale with varied image and face size.

Figure 3.4 sample images from CMU MIT database

3.2.3 FEI Face database

The FEI face database is a Brazilian face database that contains a set of face images taken between June 2005 and March 2006 at the Artificial Intelligence Laboratory of FEI in São Bernardo do Campo, São Paulo, Brazil (see http://fei.edu.br/~cet/facedatabase.html). The database contains 14 images for each of 200 persons, a total of 2800 images. All images are colored with white homogenous background and profile rotation up to 180 degrees. All the images are taken from people between 19 and 40 years old with a distinct appearance, hairstyle. The database consists an equal number of males and female.

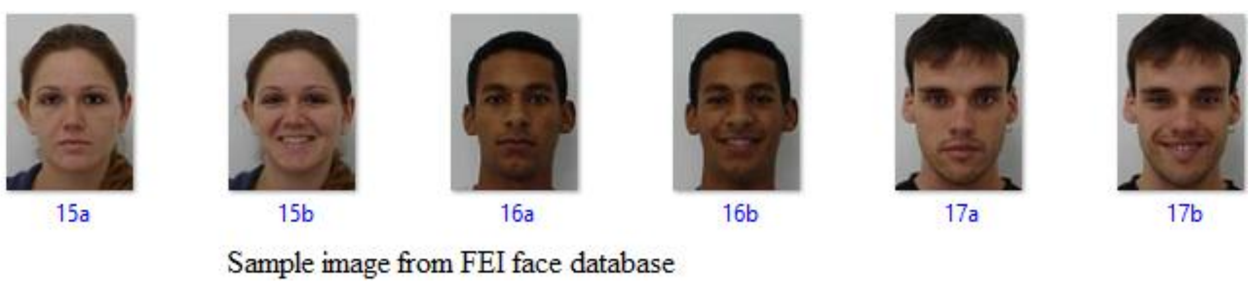


Figure 3.5 sample images from FEI face databases

3.2.4 ORL Face Databases

The ORL face database contains images of 40 individuals, each individual contains 10 face images that varying image poses, varying the lighting, facial expressions, and wearing glass; bringing the total of the images in the database to 400. The size of each image is 92x112 pixel and .pgm file format. The images are organized in 40 different directories or one directory for each subject. This database is chosen due to the availability of many instances of frontal view for each subject. More detail information is available in(http://www.cl.cam.ac.uk/research/dtg/attarchive/facedatabase.html) and the face database was downloaded from this site.

Figure 3.6 Sample image from Yale (ORL) database

3.2.5 Self-Prepared Database

Beside of using free available databases, testing the algorithm performance using self-prepared dataset is an important part of theresearch. So, we have prepared our own face databases that contain 350 images. The 200 images were collected from 40 volunteer people where each individual person contributes 5 face images with different facial expression, rotation, and illuminations. All the images are Grayscale and .PNG file format collected from January 2009 to April 2009. While the remaining 110 images are taken from different sources such as the web, and real images where each image contains one or more faces of different individuals as seen in (fig. 4.4). The whole images contain total 545faces with both Grayscale and colored image. For experiment purpose, All the images are organized in two directories and each image is identified using a name and subject number labeled on it.

Figure 3.7 Sample Self-Prepared Databases

3.4 Open Source Implementation Tools

3.4.1 OpenCV 3.1.0

For implementation purpose, we use OpenCV 3.1.0 image processing library. This library provides a common infrastructure for computer vision applications and helps computer vision researchers to easily use various computer vision algorithms. The library includes more than 2500 optimized algorithms which containinterface for various programming languages such as c, c++, java, python, and MATLAB. It also contains a set of trained classifiers for frontal face, right profile and various facial features such as eye, nose, and mouse.

The detection algorithm we employ in this implementation is a viola-jones algorithm. The haar cascaded features available inside the OpenCV library were trained based on the viola-jones algorithm. Implementing these features enabled us to detect objects or faces in real-time and offline environment. The haar cascade features would be loaded using CascadeClassifier class which is located inside the OpenCV object detection module. This enabled us to load and usesthe pre-trained face which is saved in XML file format. The face haar cascade feature provides different information such as threshold, the number of stages, the number of trees in each stage. In addition, the library provides different classes which are important for image preprocessing, image localization, feature extraction, image classification, and recognition.

3.4.2 NetBeans 8.0.2

To develop the required front end, Java programming language was used. Because Java is rich Application Programming Interface (API), platform independent, we wrote the face recognition source code using Java programming language and run on IDE 8.0.2 NetBeans as seen in the figure below.

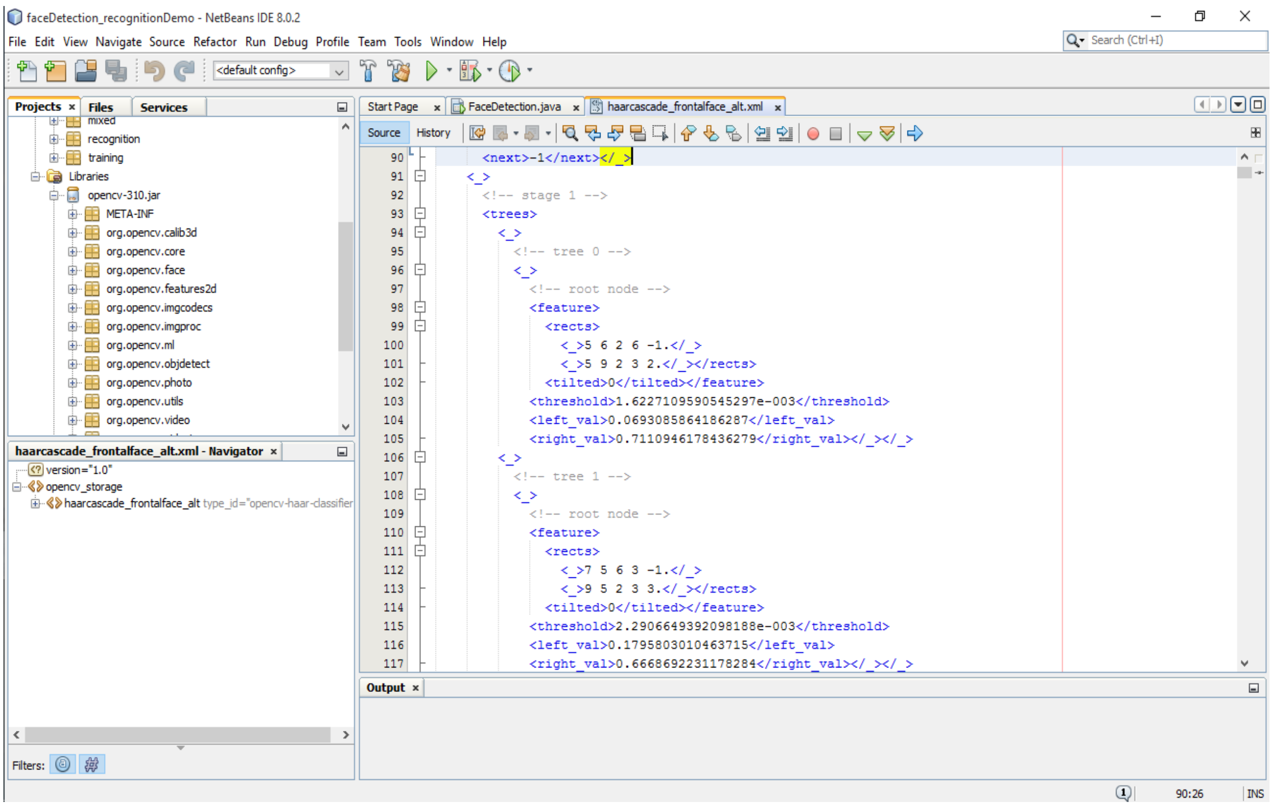


Figure 3.8NetBeans IDE with OpenCV Library

3.5Ethical Consideration

During conducting this study, various ethical considerations were taken into account. These ethical considerations applied throughout the accomplishing of this study.

3.5.1 Permission

To conduct this study, we obtain permission from Department of Computing to ensure legal exercise. The letter of permission to collect relevant information from various organizations is obtained.

3.5.2 Confidentiality and Privacy

Confidentiality refers to properly handling the information regarding the research participants in aconfidential manner. The image collected for this study was assured that in the strictest confidence. This aspect includes the principle of trust in which we assured the participants that their trust would not be exploited for personal gain or benefit, by cheating them in the research route or its published outcomes.

3.5.3 Voluntary Participation

As we describe in section 3.2.4, self-prepared image datasets were collected from voluntary participants. Therefore these participants have the right to withdraw from thestudy at any time. The principle of informed consent was verbally explained to the participants of the study. We also explained the research process and its purposes to the participants in detail.

CHAPTER FOUR

4 Proposed Face recognition System

In this section, we presenttwo mainprocedures. The first procedure is the face detections, the OpenCV cascade classifier is used to detect a face object. We applied several images preprocessing techniques such image transformation, histogram equalization, image masking and image rescaling or resizing to minimize the effect of light variation. According to our assumption, by increasing an image contrast, the face variation of the same individual will be minimized. The finalprocedure in this study is face recognition. The principal component analysis and linear discriminant analysis methods are used for recognition purpose.

4.1 Face Recognition Models

A flowchart is an important component to represent the working flow of the proposed scheme. In this study, we described a flowchart that represents the proposed face recognition system. The overall workflow of the system is described.

As figure 4.1 shown, the face recognition system includes two type of input image and generates one output. The system takes an input image or frames of a live camera. After the input is provided, then the face detection algorithm searches specific haar features that represent a face and face will be detected. Then the detected image will be sent to image preprocessing stage for further enhancement image contrast, size, remove image nose, and remove corner image. Finally, the face recognition algorithm identifies the identity of an individual. The overall output of this proposed scheme supports image and text output result.

In general our proposed model is divided intofour different phase asseen in figure 4.1. The initial phase concerns with the image capturing, preprocessing,face detection, and database preparation. First individual images are captured from the online camera or file directories. Once the images are captured, then various preprocessing techniques are applied to standardize the image quality. Then, the face detection algorithm iteratively searches the face region from the input image and detect if face feature is available on the image. In the second phase, features vectors are extracted from the training dataset using PCA and LDA feature extraction techniques. The testing phase also follows the same procedure as the first and second phase, such that the individual images are acquired from camera or file, face detected using viola jones framework, preprocessed and the feature vector of a testing image is extracted to compare with the feature vector of a training image. The final phase concerned with validation of individual faces and integration of the system with some external systems.

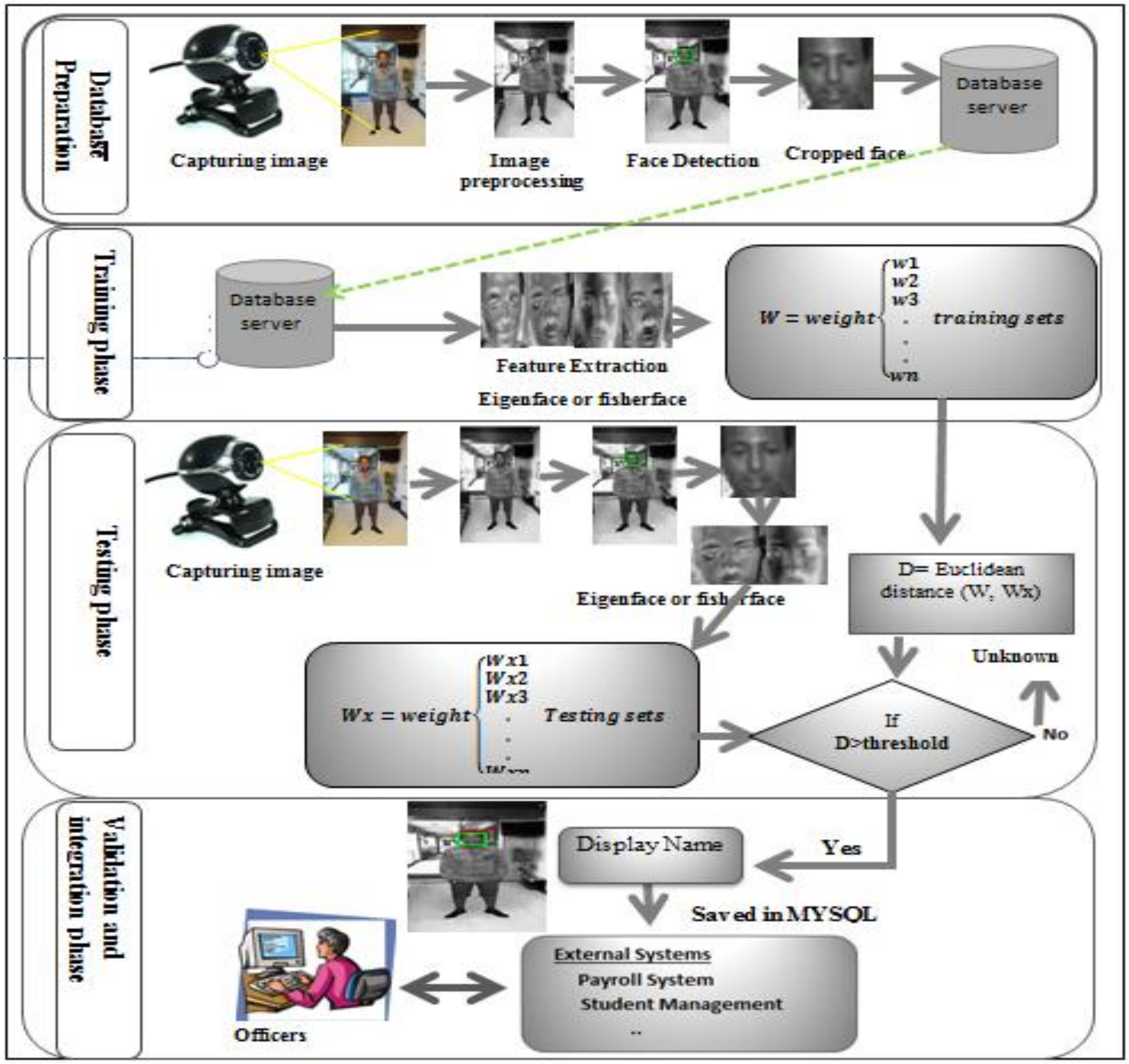


Figure 4.1 Proposed Face Recognition Framework

The proposed face recognition systemis based upon a five-stage pipeline.The image acquisition, pre-processing, face detection, feature extraction, and classification could run simultaneously.

Face acquisition is the process of acquiring the face image using the camera or through another mechanism. After face image has been acquired from web camera or afile, then the process of extracting or detecting aface region from the input image will continue. This process has many applications such as face tracking, pose estimation. The face detection will be followed by preprocessing to eliminate the factors that influence the performance of the recognizer like thevariance in illumination, pose, and noise. The fourth step is a feature extraction which enables as to obtain relevant facial features from the detected image. These features may be face regions, angles or measures, which can be human-relevant information or not. Finally, the system identifies the identity of the face, by comparison,each face with the database image.

4.3 Image Acquisition

According to Sadi Vural [4], acquisition the digital face image of an individual is the initial step in a typical face recognition system. It is a module where the face image under consideration is presented to the face recognition system. The image may acquire from several environments. The digital face image may be acquired from image directory which is located on the disk or it can be captured frame grabber using light-sensitive cameras such as range sensors, IP camera, radar, ultrasonic cameras [73]. The image quality, image dimensionality, and resolution depend on the type of sensor used.

In this study, the experiment is conducted based on the standalone personal computer with a build in camera. The computer requirement used in this experiment is an Intel I3 with 2.50GHz speed and internal memory 4GB. The graphics card used Intel(R) graphics 4000 with HD Toshiba web camera used for image acquisition purpose.

4.4 Face Detection

Face detection is computer vision technology which can be defined as the localization and extraction of the face region from the background of the image without considering the identity of the face. A typical face recognition system may or may not require face detection. The face detection method may not require in case of face images stored in the database are already normalized. For instance, in a criminal database, the lawenforcement agency stores face of people with a criminal report. If there is new subject and the police have his or her passport photograph, face detection is not necessary [78]. However, face detection is necessary for face recognition systems, because a single input image may contain multiple faces or background image. Therefore, it is important to assume that a face detection as part of the more ample face recognition problem.

There are plenty of methods available to deal with face detection problems. But there is no globally accepted criterion to givetaxonomy of these methods. As described in section 2.2, the face detection algorithms divided into color-based approaches, template-based approaches, and feature-based approaches. Each of these approaches has their own merit and demerit over the other approaches. For example, some recent research works use a color model and achieve a good result, but color models can vary significantly if light conditions change.

In our work, we have used a feature-based technique to detect a face region from the input image or video stream. As described in [11, 12,30, 64], Viola-Jones algorithm is one among the most commonly used feature-based method for face detection. Table 4.1 describes the appliedsteps classifier for detection.

Table 4.1 face detection procedure

Algorithm	*Face detection*
Input	*image dataset or real-time image frame*
Output	*Face*

First define:

Define VideoCapture as webSource

Define the cvMatrix as frame;

Define CascadeClassifier as faceDetector;

Define MatOfRect as rectangleMatrix //

Define cv::Rect[] as arrayRactangle

Define displayScreen;

Next step is:

Initialize the camera for real timeor load the face image for non-real time detection

Load the OpenCV CascadeClassifier

Check if camera is start or image is loaded

Retrieve the frame as frame

Load the face detector to memory based on the frontal face cascade classifier

Convert the rectangleMatrix to array

Set rectangleMatrix array to arrayRactangle

Set detector dimensionality

if (face feature is available){

Load face features from memory

Create cv::Points on the arrayRactangle

Draw rectangle on the image or frame

Return faceimage

4.4.1How the cascade Classifier Works

As described in [11, 12,30, 64], the OpenCV cascade classifier was trained based on the viola-jones methods. The viola-jones has four basic general ideaswhich are necessary to build an efficient face detection system. In this study,we apply these ideas as shown in figure 4.2. The first conceptincludes a simple rectangle feature called haar-like feature and evaluated quickly through image representation. The second concept is the integral image which is necessary to evaluate the absence and presence of haar feature at every image. The third concept is the AdaBoost machine learning algorithm which is used to select simple and efficient classifiers for deciding whether the candidate feature is a face or not [2].

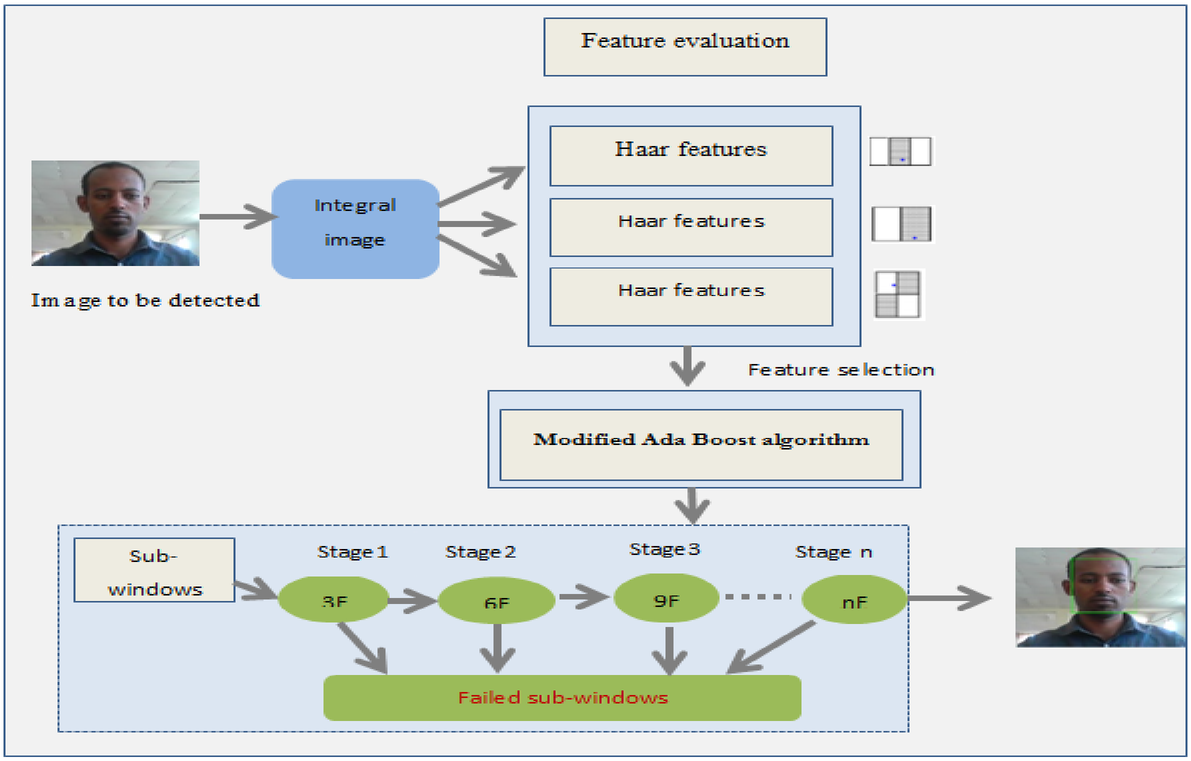


Figure 4.2 Viola and Jones face detection Procedures

4.4.2 Haar-Like Features

Since the Viola and Jones algorithm is being used as the foundation of face detection design in our study, an image is classified as face based on the value of rectangle features. Using simple features other than intensity pixel value has many advantages because feature based systems are faster than pixel based system [2]. According [19] thehaar feature can be composed of two, three or four rectangle feature. These rectangle features are adjusted either horizontal, vertically, or diagonal with the same size and shape but light and dark color. The value of the rectangle feature is the differences in grayscale intensity between the sums of the dark and white region as shown in figure 4.3. If the value acquired during training is above the specified threshold, then we can say that a feature is present.

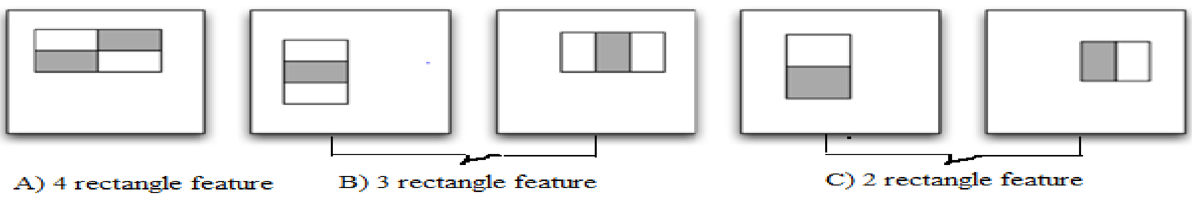


Figure 4.3 Examples of haar features

The completefrontal face detection of this study has total 2134features. This total number of features segmented into 22 different stages. Each stage can have different number of features Depending on the parameters of the training data. The number of features in the first four stages of the detector is 3, 16, 21, and 39 features respectively. The remaining stages have increasingly more features. A stage comparator sums all the Haar feature classifier results in a stage and compares this summation with a stage threshold. The threshold is also a constant obtained from the AdaBoost algorithm.

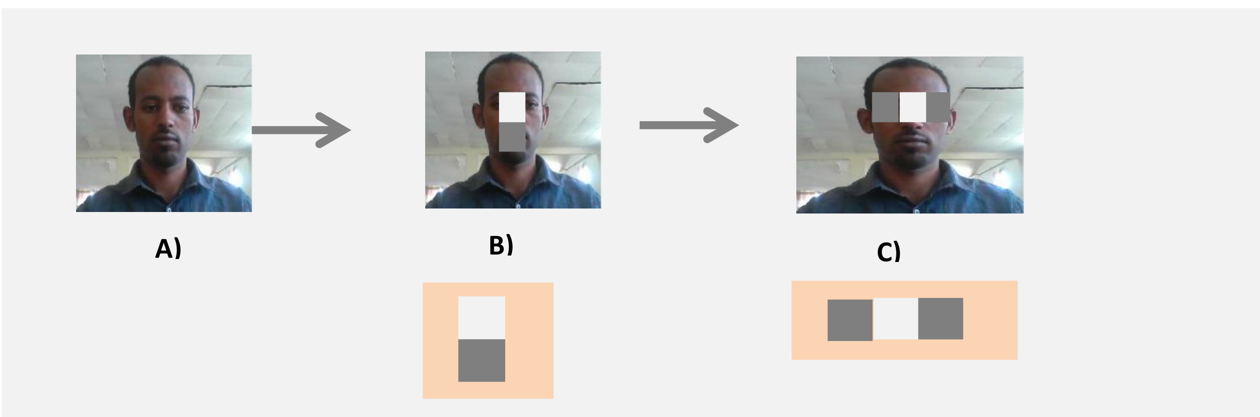


Figure 4.4 Examples of haar features

4.4.3 Integral Image

The rectangle feature of an object can be computed rapidly using an intermediate image representation called integral image. It is a matrix made to simplify the calculation of the value of an upright rectangular area in an image [59]. The value integral image at the point i(x, y) is the sum of all the pixels from the original image above and to the left of i(x, y). For theoriginal imagei(x, y) the integral image can be defined as:

$$ii(x,y) = \sum_{x \le x', y \le y'} i(x', y') \qquad (4.1)$$

The i(x’, y’) is the image to be processed whereas the ii(x, y) is an integral image. The integral image can be computed in one pass over the original image [4][2] using the formula below.

$$s(x, y) = s(x, y-1) + i(x, y)$$
$$ii(x, y) = ii(x-1, y) + s(x, y)$$

Where s(x, y) is the cumulative sum rows and i(x, -1) =0 and s(-1, y) =0 and then finally equation (2) is formed as.

$$ii(x, y) = ii(x-1, y) + ii(x, y-1) - ii(x-1, y-1) + i(x, y) \qquad (4.2)$$

Where I(x, y) is an original image whereas ii(x, y) is an integral image [59]

For example, table 4.2 shows clear demonstration how rectangle feature of an object is computed.

Table 4.2 Original and corresponding calculated Integral image

155	201	226
98	78	48
14	111	44

155	356	582
253	532	806
267	657	975

With the help of an integral image, four array references are used for calculating a single rectangle feature, six array references for two adjacent rectangles, eight array references for three adjacent rectangles and nine array references for four adjacent rectangles. To calculate the area of the rectangle shown in figure 4.4, we can use the equation below.

$$area = image(A) - image(B) - image(D) + image(C) \qquad (4.3)$$

For example, as figure 4.5 shown the sum of the pixels within rectangle D can be computed with four array references

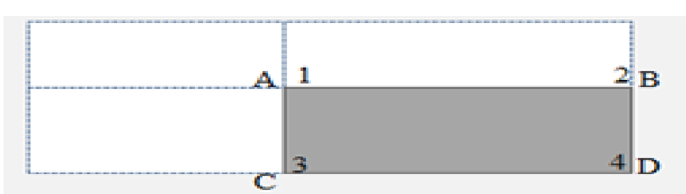


Figure 4.5 Computing Rectangle Areas using Integral Image

The integral image value at location 1 can be calculated as the sum of the pixel in rectangle A. whereas at location 2 is A+B, A+C at location 3, and A+B+C+D at location D. Once the integral image is calculated, the rectangle D is computed as:

$$4+1-(2+3) = A+A+B+C+D-(A+B+A+C) \qquad (4.4)$$

$$=2A-2A+B-B+C-C+D$$

$$=D$$

4.4.4 Adaptive Boosting (AdaBoost) Algorithm

Boosting is a technique which is used to combine a number of weak classifiers to create a single strong classifier [58][60]. the number of classifiers ranging from a simple 2-feature up to more complex layer that containing a large number of features is combined in a cascade structure for providing both accuracy and real-time processing [13]. The AdaBoost algorithm trains the classifier using a positive image that contains aface and negative image without a face for selecting the best subset of features. The search window iteratively scans and moves across the entire image and represents every particular section a face candidate using the classifier. The scanning window can be easily resized to find the face objects of different sizes. This is more important than resizing the image itself. As Julien Meynet [60] presented in hisresearch work, the AdaBoost algorithm has two basics (see in figure 4.6). First, selecting a few features that represent faces from an array of features. Secondly, the AdaBoost algorithm iterates over a number of T stages as shown in figure 4.7 and in each stage, all possible features are searched exhaustively to train weak classifiers that consist of one single strong feature [61].

Figure 4.6 Adaptive boosting algorithm schemes [61]

This is an efficient method which reduces not only the training error but also reduces more elusive generalization error [61]. As figure 4.6 shown, the AdaBoost algorithm does not require prior knowledge about the face structure. Only the training dataset and the set of features are needed for selecting the most representative features during the learning.

4.4.5 Cascade Classifier

Viola and Jones also introduce an idea of cascading classifier to reduce the computational time and achieve high performance. In cascading scenario, smaller and more efficient classifier can be constructed by rejecting the negative scanned window and detecting all positive instances. To find the face object in the image, the scanning window should be scan and move across the entire image several times at different scale. If the sub-window under tested failsat an early stage, it will be discarded and no further processing is performed.

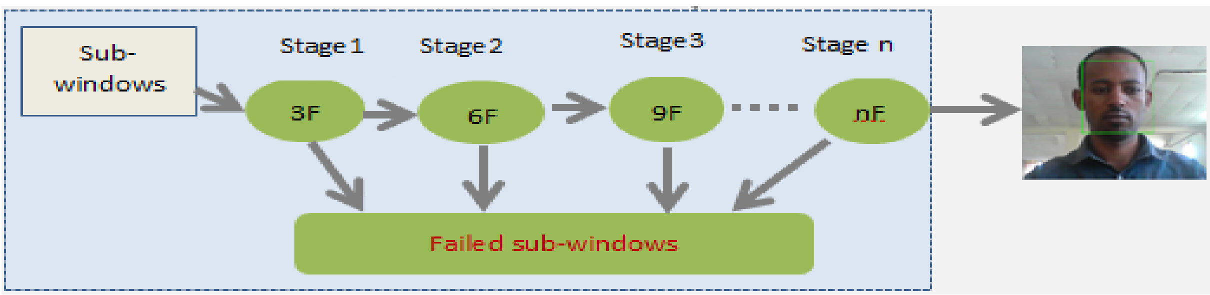


Figure 4.7 Cascade stages of viola-jones algorithm

The computational time of the detector can be reduced by combining several strong classifiers into a cascade. Simpler and faster classifiers are used in the initial stage of the cascade because most of the images' region scanned into the first stage is non-face. However, the next stage of the cascade uses a more complex classifier to further reduce the overall false positive rate. The sub-window of an image can be accepted if they have passed every stage of the cascade [28].

Observe figure 4.7, the 3F indicates the number of features used in the first cascade stage. The input image is evaluated against the accepted threshold value on the initial cascade stage and if the detection rate greater or equal to a given value and false positive rate less than or equal to a given value then the image passed to next stage (1). If the above condition fails to meet, then computation on that stage ends up. This procedure will continue through all stages in the same manner as the previous. If the image passes through all stages successfully, then the image will be returned as a face. All these evaluation procedures are done through the AdaBoost algorithm for deciding whether the candidate image has a face or not after each classifier [4].

In this study, we used cascading to produce an effective classifier which is highly efficient. The complete face detection of the study has total 22 stages. Each stage is trained by adding features until the target detection and false positives rates are met. The number of features in the first fourstages of the detector is 3, 16, 21, and39 features respectively. The remaining stages have increasingly more features. The complete face detection cascade has 22 stages with 2134 features.

4.5 Pre-Processing

The output from the face detection step would result in a set of possible faces that require a preprocessing. A face recognition algorithm requires image preparation because methods such as PCA and LDA are sensitive to thevariation of pixel intensity that may be caused by background differences, hairstyles, image size, and pose variation.

The main purpose of applying image preprocessing is necessary to remove information which is not relevant for feature extraction.Many researchers have presented several research works to conduct preprocessing before going into face recognition phase. As described in [99] themain purpose of image pre-processing is to produce a clear image data for the processing phase. Some image preprocessing includes Image transformation,image resizing, histogram equalization and Geometric normalization.

For image preprocessing purpose, we apply several OpenCV classes/methods such as Mat, Rect, Resize, and cvtColor (). The Mat class of OpenCV library represents the n-dimensional array which is used to store the value of image data. The Rect class represents a2Drectangle with coordinates of x and y that represents the top-left corner, and the width and height represent the rectangle. The cvtColor method found in the Imgproc class is a color converter which used to convert from one color space to another. The cvtColor method takes three parameters which are the source image matrix, the destination image matrix, and the color conversion type. The Resize ()method of an OpenCV library is used to rescale to aparticular size.This is done based on the size which contains two parameters namely width and height. The resize() method takes three basic parameters which are input image, resized image and image size with the specified row and columns.

Table 4.3 Image preprocessing procedure

Algorithm 4.2	Preprocessing
Input	Detected face image
Output	Preprocessed face image
Define cv::Mat ResizeImage	
Define cv:Size as size	
Define cv:Mat grayscaleImage	
Define cv::Mat histogramEqualized	
Set the new image size row and column	
Resize the image to new image size	
Convert the frame color to Grayscale frame	
Convert to histogram equalized image	
Define bilateralFilterto reduce pixel noise by smoothing the image	
Filter out the corners of the face, since we mainly just care about the middle parts.	
Draw a filled ellipse in the middle of the face-sized image.	
Apply the elliptical mask on the face.	
Return maskedface	

4.5.1 Image Transformation to Grayscale

Based on the Algorithm 4.2, we transform the colored frame/image to the Grayscale frame/image. For this purpose, weutilizepre-processing functions available in OpenCV to convert the RGB image to Grayscale image as shown in thefigure below. Utilizing Grayscale image has many advantages such as data compression and minimizes memory utilization. Figure 4.8 shows image transformation fromRGB to grayscale.

Figure 4.8 Image Transformation

4.5.2 Histogram Equalization

As we discussed in section1.1, variation in illumination can dramatically reduce the face recognition performance. Multiple images from a single person can be taken invariant light conditions. Some image may be taken at high contrast and others images at low contrast. Therefore the histogram equalization is asimpleand robust way to adjust and correct the contrast of an image. It is important to maximize the contrast of an input image, resulting in a histogram of the output image which is as close to a uniform histogram as possible [9].This makes facial recognition system more easy and simple.

A) Grayscale image B) Histogram equalized

Figure 4.9 Grayscale and histogram equalized image

Figure4.9shows the process how histogram equalization will be appliedto theimage to enhance the face recognition system.

4.5.3 Image Rescaling

Imagerescaling or resizing is another important preprocessing step we apply in this study for rescaling the dimensionality of an image.The input image in this study is reduced to the size ofN*N pixel where N=40, 80, 128, 150, and 250.

Figure 4.10 Face Image Resizing

4.5.4 Face Masking

Most of face recognition approaches are unable to differentiate between hair (not a face feature), background at around image border and a face feature, so hair gets misinterpreted as a face characteristic.Therefore image masking is required to remove outer features such as ears, hair, and background that influence face variation.

The faces in the ORL, FEI and self-prepared databases had frequent hair features that were not removable using hair removal algorithm.Most of the images in the database had hair features. So we apply masking to remove the hair and ear part of the image.

A) Grayscale image B) Histogram equalized C) Masked Image

Figure 4.11 Image masking process

4.6Face Recognition Algorithms

After the image has been preprocessed, the prominent features should be extracted without losing basic information. Several feature extraction techniques are presented in the literature review in chapter two. These feature extraction techniques are divided into three face recognition approaches namely: ananalytical approach, holistic approach, and hybrid approach. The hybrid approach performs recognition by combining both holistic and local features [98].

In this study, the principal component analysis and linear discriminant analysis have been chosen for our experiment. Both PCA and LDA require low memory, low computational complexity and takes less time to execute. These factors are important criteria to apply holistic method feature extraction techniques.

4.6.1 Principal Component Analysis (PCA)

In computer technology, mostly in the context of Big Data, data is expressed in terms of vector and matrices [75]. But in thecase of animage, the images with higher resolution mean the size of the matrix is larger. Therefore, a method is required to reduce the dimensionality of the dataset.

The principal component analysis is a dimension reduction method which was first introduced by Karl Pearson in 1901[66] and later extended to use in face recognition by Sirovich & Kirby and Turk and Pentland [74] respectively. It is a well-known holistic based statistical technique that can be used in many areas like face recognition, image representation, pattern recognition, computer robotics, and data compression [2]. It considers the entire data set as a whole without taking into account the labeled classes within the dataset [67].

In face recognition system, the PCA search the small number of features which are defined by the principal components of the face. And then principal components can be found by projecting the high dimensionality of the face images into a low dimensionality of subspace. These are necessary to define the data economically [4]. More specifically, the principal components of face images can be computed by solving the Eigenvectors and Eigenvalues of a covariance matrix. The first principal component represents the variables in the original dimensions or data set with maximum variance and each succeeding component is the linear combination the highest variance[2][66]. The eigenvectors represent the direction of PCA of the original image and their statistical significance is given by their corresponding eigenvalues [11]. The Eigenvectors with a small number of features indicates dissimilarity among faces in the dataset, but the Eigenvectors with thehighest feature represent similarity. The dimensional reduction can be achieved by discarding principal components that possess low feature. This is important to maximize the efficiency memory storage and run-time exclusion.

4.6.2 Basic Steps of PCA Algorithm

In order to create Eigenfaces in this study, we follow the general process proposed by Alex Pentland et al [74]. First, a set of training images is defined as $\Gamma_1, \Gamma_2, \Gamma_3 \ldots \Gamma_N$ where N is the image to be processed.The eigenface spaces are easily obtained by applying the eigenface method on the set of training images. After the eigenface space has been created, the training faces are projected into eigenface space. This will be followed by projection of the test images into the new space and the distance of the projected test image to the training image is used to classify the test image. This technique is suitable and efficient for any face recognition system due to its simplicity, speed, and learning capability. Figure 4.12 demonstrates how individual person will be identified from a collection of training using PCA techniques

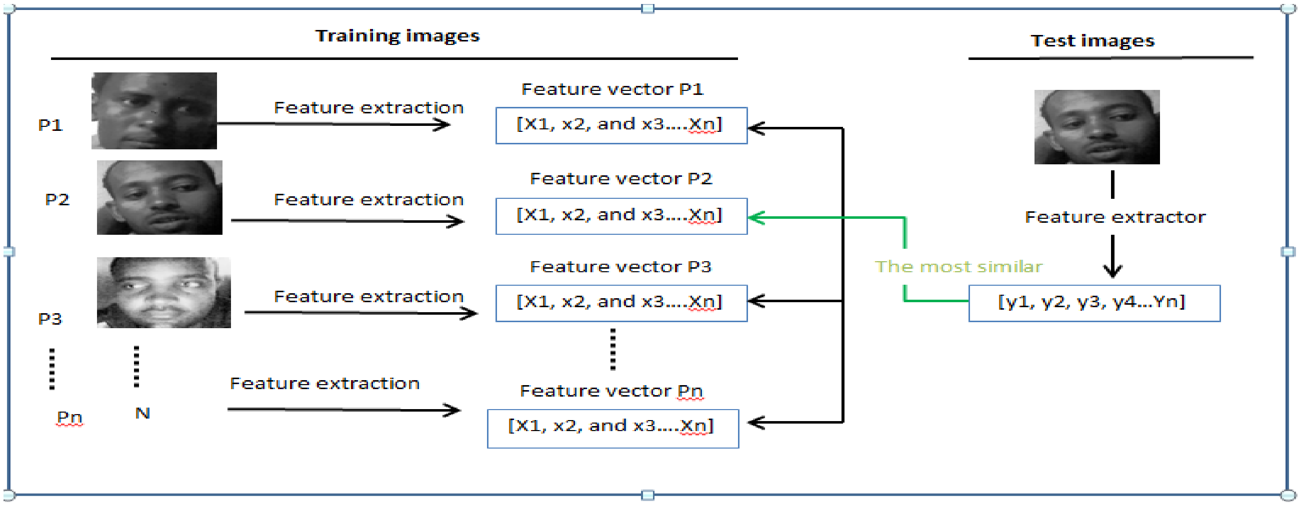


Figure 4.12 PCA feature extraction

As demonstrated in figure 4.1, a face recognition system that uses PCA has to go with several steps, including train the recognizer using both positive and negative train sets. But before starting with each step, we should first prepare a training set and load it into the system. Assume that the training set consists of total M images with size NxN.

Once we have prepared the training images, then the next step is training the recognizer using the prepared datasets as follow.

1. **Step1:** in the early stage, we should have to convert each face image in the training set to face vectors. Suppose we have a training face images $\Gamma(x, y)$ be two dimensional NxN array sizes of 8-bit intensity value. These images can be considered as a vector of dimension N^2 or a point in dimensional space [66][11]. For instance, a typical image with a size of 128x128 is the same as vector of dimension 16,384 or equivalently a point in 16,384 -dimensional space. This clearly justified in the figure 4.13 where a face database with M training face images are mapped to a set of points in the high-dimensional face space as $\Gamma 1, \Gamma 2, \Gamma 3, \dots, \Gamma M$.

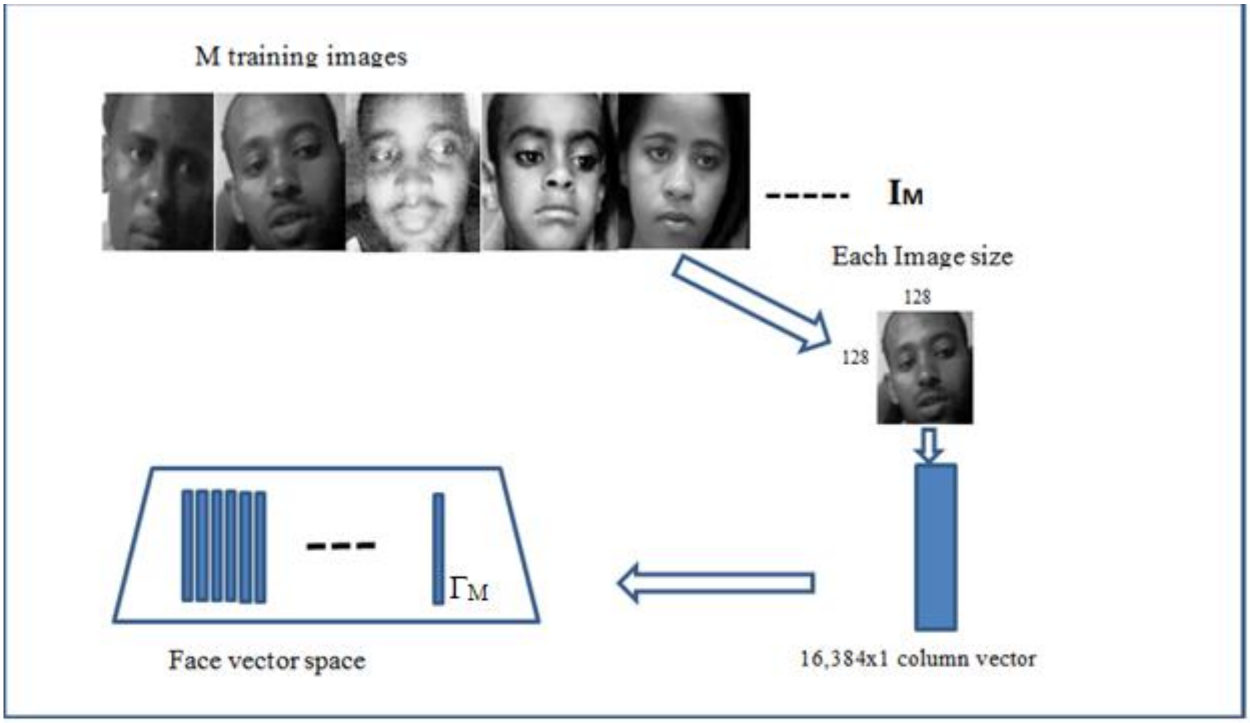


Figure 4.13 Converting Face Image into Face Vectors

2. Step2:

After converting the training set to face vector, we now normalize the face vector which means that any common feature shared by all faces in the training set should be removed from each face vectors, therefore, each face only left with unique features that identify that face. This can be true by computing a mean average face image (vector) that contains all common characteristics of the images in the training set such as the nose, the eyes, and the mouth. The mean average face is found using theformula below.

$$\Psi = \frac{1}{M}\sum_{n=1}^{M}\Gamma n \qquad (4.5)$$

Where Ψ is the average image vector, M the number of sample face vectors, and Γn is a random vector. The average face for three datasets is shown below in Figure 4.14.

Figure 4.14 mean images of three different training datasets

Once we have computed the average image, then, each face image will be processedby subtracting the average image to obtaina new set of face images marked byϕ_n as equation below.

$$\phi_n = \Gamma_n - \Psi \qquad (4.6)$$

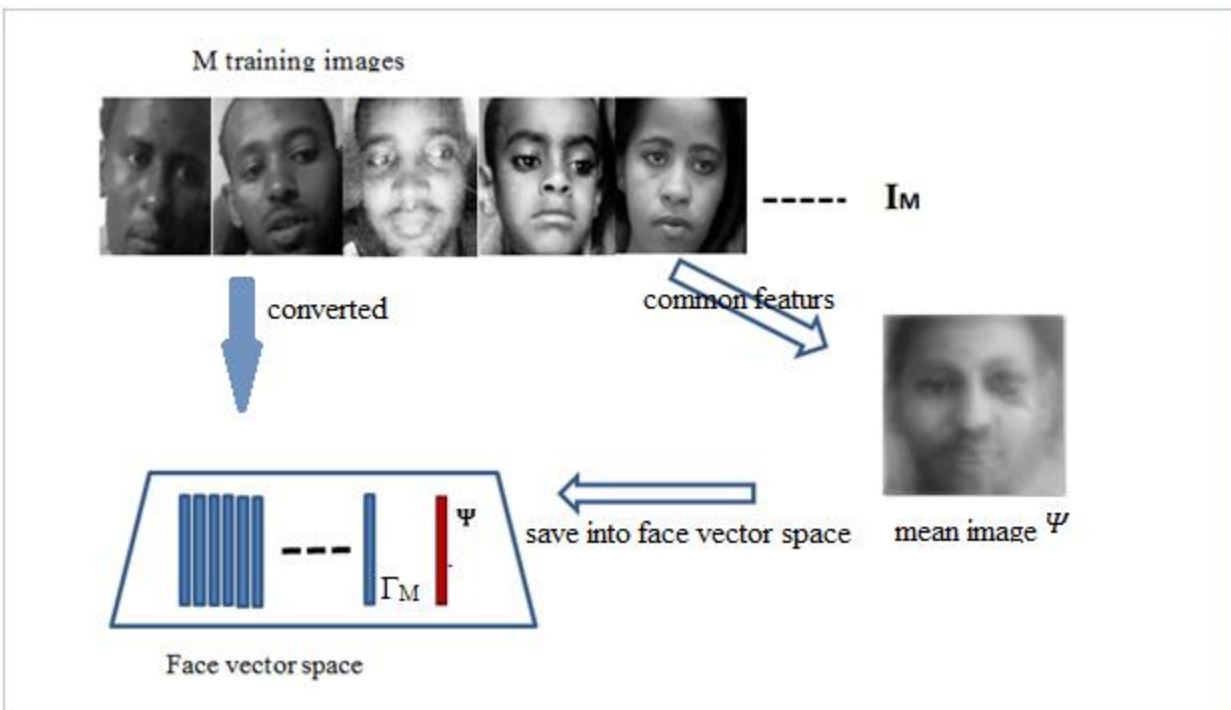


Figure 4.15 Converting face image into face vectors

3. Step3:calculating the covariance matrix:

As Peng Peng [75] describes in his master thesis, various statistical techniques such as mean values, standard deviation, and variance are used to analyze the distribution and variation of a set of data. These techniques only work for one-dimension data, however,in acomputer system, image data are multi-dimension. Using the covariance technique, the relationship among data of different dimension can be easily calculated. The covariance matrix C of these set of images can be calculated using theequation below.

$$C = \frac{1}{M}\sum_{n=1}^{M} \phi_n \phi_n^T = AA^T \qquad (4.7)$$

Where $A = [\phi_1\phi_2 \dots \phi_M]$a normalized face vector or mean adjusted images.It can be also expressed as A=$N^2 * M$ since dimension of M face images are N*N. Figure 4.16 includes derived formula to calculate the covariance matrix.

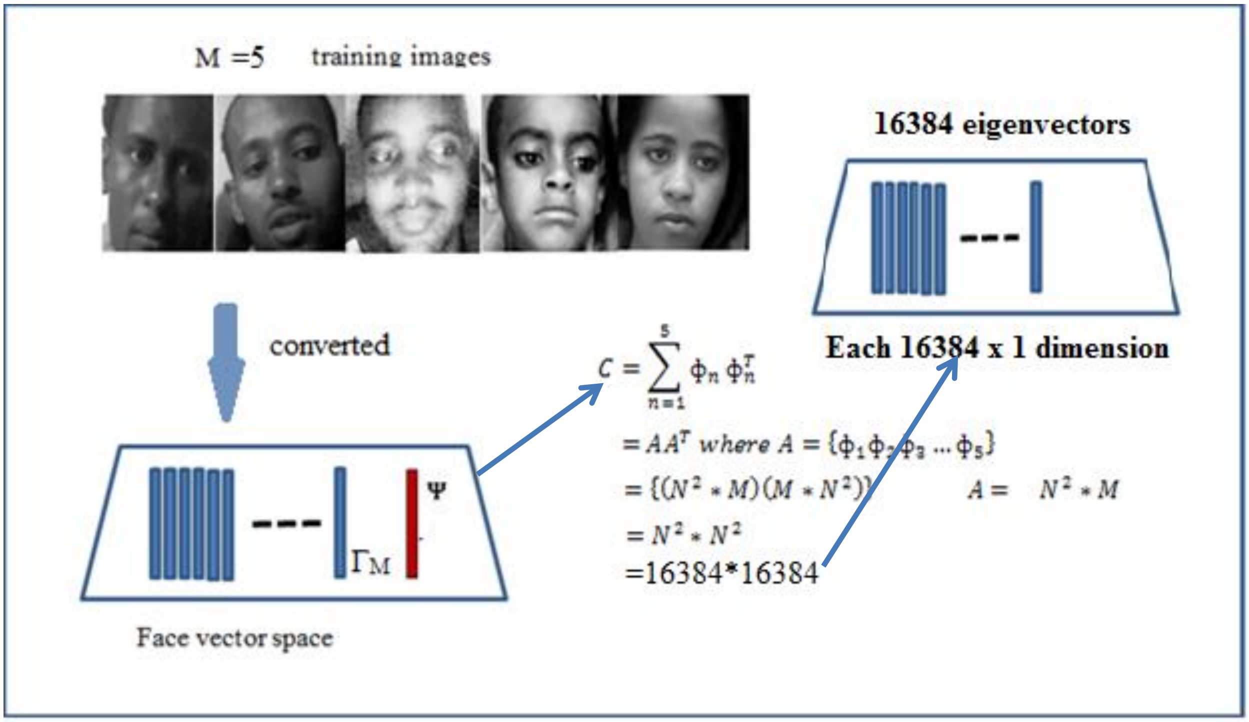


Figure 4.16 Calculating covariance matrixes

The covariance matrix (C) with dimension N^2*N^2 is very large. For example, an image M=5 with adimension of 128*128 becomes covariance matrix 16384*16384. This means 16384 eigenvectors are generated.

4. Step4: calculating eigenvector and eigenvalue from the covariance matrix

By using PCA method the eigenvectors and eigenvalues can be obtained from the covariance matrix with a dimension of $N^2 \times N^2$. Calculating eigenvectors and eigenvalues from this covariance matrix is very difficult to work with due to its huge dimension causing complexity. An image size of 128*128 will generates 128 rows witha same number of column. It is very hard and requires a computational resource to store such complex matrix. To reduce the number of resources required, a method for encoding and decoding information is necessary. Therefore, it is possible tocompute the eigenvector (Vi) and eigenvalue (μi)as L matrix [11, 98]. Since matrix AA^T is very large a new $M * M$ matrix called L can be constructed [66].

$$L = A^T A \quad (4.8)$$

Then the eigenvector Vi and the eigenvalue μi of L are obtained

$$L.Vi = \text{μi}.\ Vi \quad (4.9)$$

From Eq. 3.8 the value of L can be asubstitute to Eq. 3.9

$$A^T A.Vi = \text{μi}.\ Vi \quad (4.10)$$

Multiply both sides by A

$$A.A^T.A.Vi = \text{μi}.A.Vi \quad (4.11)$$

$$= C.A.Vi = \text{μi}.A.Vi$$

Since μi is a scalar it can be substituted $A.Vi$ by μi and generate as below question.

$$\text{μi} = A.Vi \quad (4.12)$$

The above question indicates the possibility to obtain the eigenvector of L using the eigenvector C, which means theMxM matrix is utilized instead of $N^2 {*} N^2$. in other word, theVi is an Eigen vector of C and L where $A.Vi$ is an eigenvectors of C and the M eigenvectors of L are used to form M eigenvectors of μi of C that form eigenface [11]. Both$A^T.A$ and $A.A^T$ have similar eigenvalue and eigenvector. By using this calculation, we can greatly reduce the number of pixels in the images (N^2) to the number of images in the training set (M), since the training set of face images (M) are smaller than the number pixel in the images (N^2). The eigenvectors can be considered as vectors points of the maximum variance and the eigenvalue is directly proportional to the variance in eigenvector [66]. Therefore, the eigenvectors are ranked based on the corresponding eigenvalues. The eigenvector having the largest eigenvalue is marked as the first eigenvector, and so on. In this manner, the most generalizing eigenvector comes first in the eigenvector matrix.

5. Steps: Selecting eigenface

As indicated in step 4, the eigenvectors are ranked based on the eigenvalue and each eigenvector consists of thedifferent amount of variance among face images. This eigenvector can be thought as a set of features that describes the variance between face images. Each image location contributes more or less to each eigenvector; therefore it is important to rank each individual's eigenvectors as a distinct feature called eigenface. Eigenface with the most significant component is ranked at first in the top left image and decreases it's significant as we go to the right bottom of the eigenface image. This order is adjusted the corresponding eigenvalues. The eigenvector having the largest eigenvalue is marked as the first eigenvector and the smallest eigenvalue as the last eigenvector.

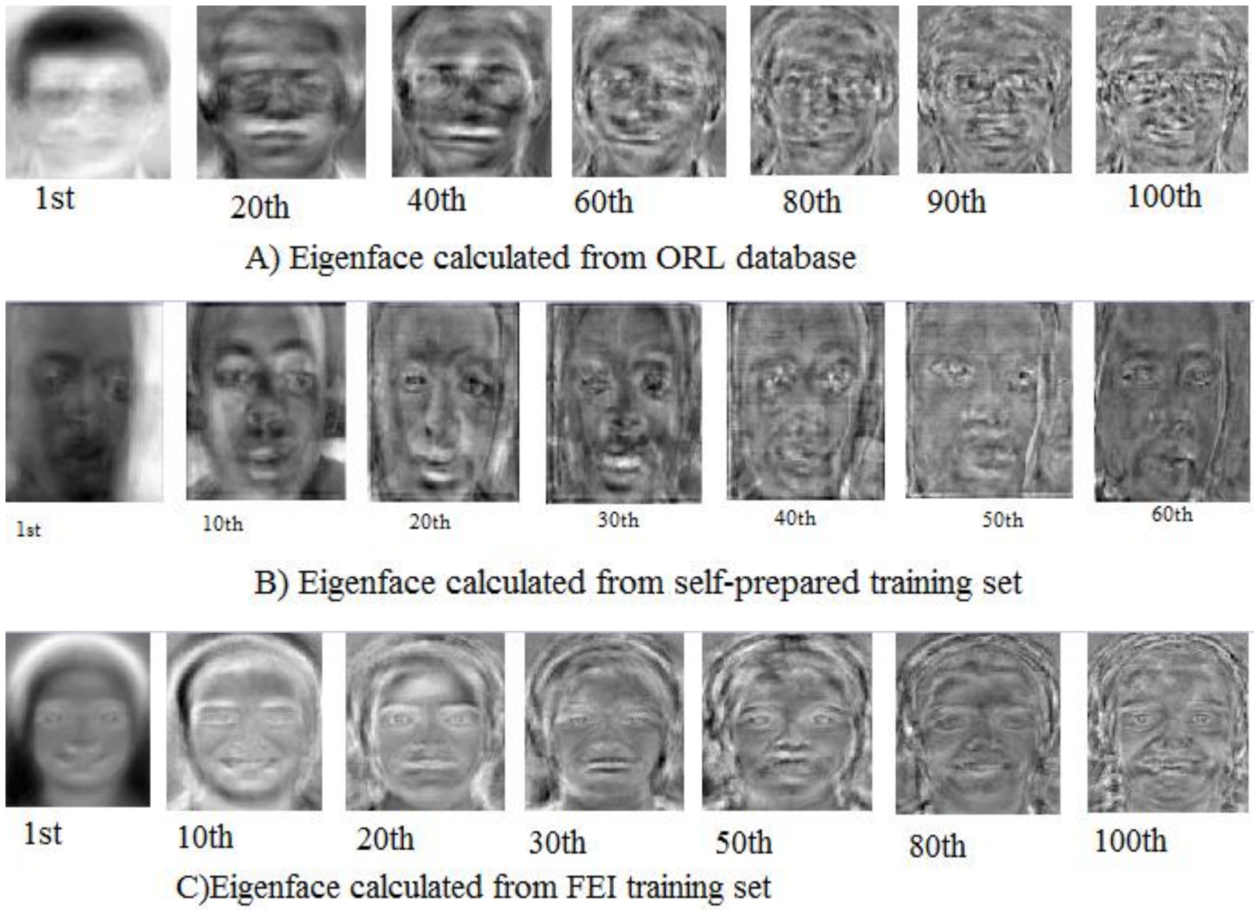


Figure 4.17 Eigenfaces generated from three databases

Figure 4.17 shows that as the number of eigenface increases, their respective Eigenvalues decrease, and the image becomes nosiest. This progression is expected because the size of the Eigenvalue determines the relevance of the corresponding Eigenface. Observe figure above, the facial features of the 1st eigenface are visible but in the 100th Eigenface, there is much more noise. The 30^{th}, 50^{th}, and 80^{th} eigenfaces are relatively clear but the visibility gradually decreases from the first to last eigenface.

STEP 6: Select the best Eigenface: Only few K Eigenvectors with highest eigenvalues are needed to represent the entire dataset. WhereK<M and M represents the whole dataset. The eigenvector with small eigenvalue shows fewer features and more noise. In this stage, only small

principal component K was selected and the remain component will be discarded see in figure 4.18

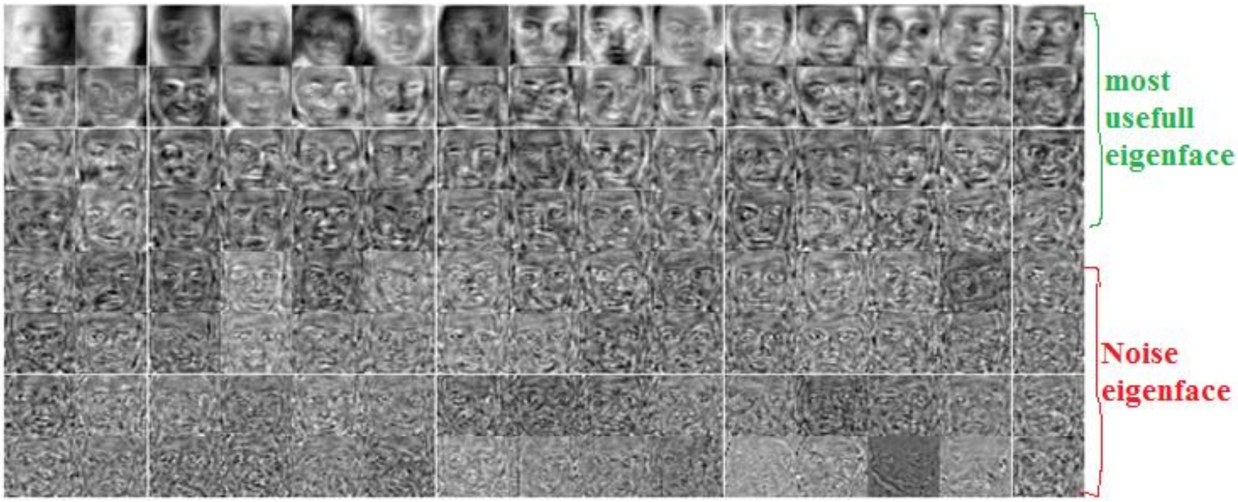


Figure 4.18 Select the best Eigenface

4.6.3 Linear Discriminant Analysis (LDA) Based Face Recognition

The Linear Discriminant Analysis is known as Fisher Linear Discriminant [67, 23], which is a supervised learning algorithm used for feature extraction and dimension reduction. This has been used in several research areas such as face recognition, image retrieval and etc [2]. Unlike PCA which uses scatter matrices to reconstruct an image from a low dimensional, the LDA uses discriminant subspace that minimizes the scatter between images of the same class and maximizes the scatter between different class images [93]. Fisher discriminants are used to group images of the same classes and separate images of different classes. Here, images are projected from N^2-dimensional space to M-1 dimension space, where N and M are the numbers of pixels and number of classes in the image respectively. for instance, figure 4.19 shown that two sets of points colored by green and blue in 2 dimension space are projected to a single line hence depending on the direction of theline, the points can be either mixed together(figure 4.19a) or separated (figure 4.19b). To identify input test image, the distance of a projected test image is compared with each training image and then the test image closest to training image is identified.

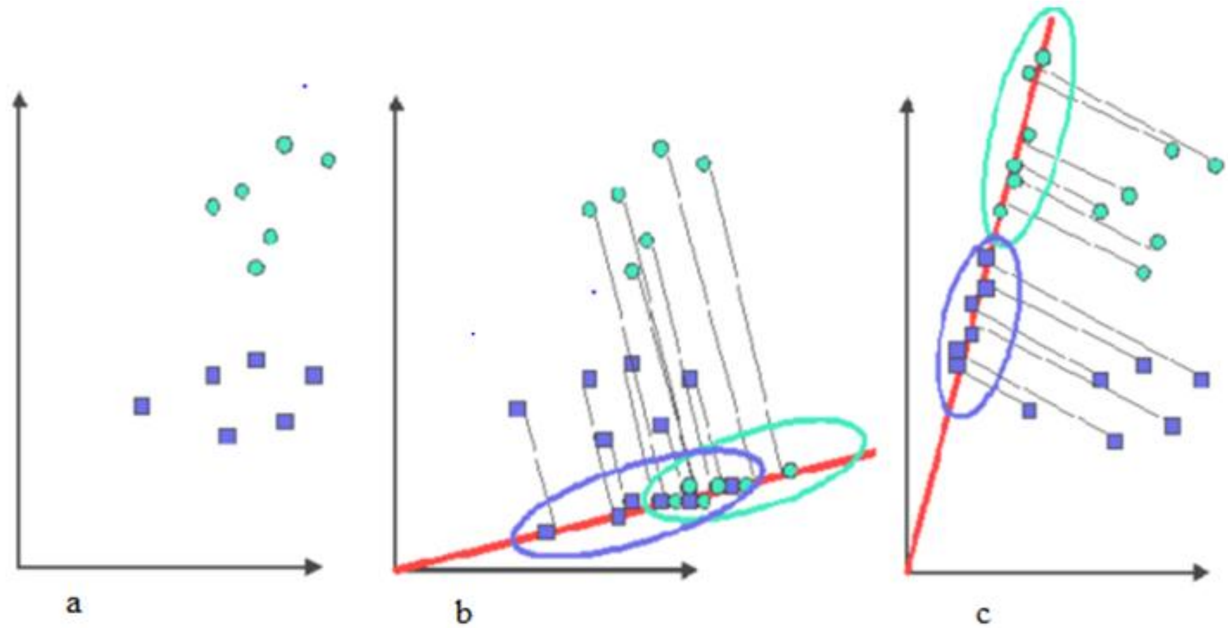


Figure 4.19 a) points in two-dimension space b) points mixed during projection (bad separation) c) points separated during projection (good separation)[11]

Fisherfaces method uses Linear Discriminant Analysis (LDA) to find the subspace within which a set a sample face images can be represented [93]. This is similar to eigenface method which is based on the projection a training face image into a subspace. Similarly, test images are projected into subspaces and similarity measure is used to identify that face. But these two methods are different in the way subspace calculation performed. In eigenface method, PCA is used for dimension reduction which yields directions that maximize the total scatter across all classes of images [11], in other words, features are extracted to best represent face images. This is important to reconstruct animage from low dimension basis but it is not effective to create an optimal discrimination for different classes. While using LDA method, theoptimal projection can be readily computed by applying Eigen decomposition on the scatter matrix [2]. It maximizes the ratio of the determinant of between-class scatters matrix of the projected samples to the determinant of the within-class scatter matrix of the projected samples.

The linear Discriminant analysis between-class can be defined as $B_s$and within-class scatter matrixW_s. the within-class scatter matrix W_s also known as intra-personal which represents variations in face appearance of the same individuals caused due to different light condition and facial expression, while between-class scatter matrix $B_s$represents variation in face appearance due to identity difference. Therefore, by using the LDA method, the projection subspace maximizes the distance between face images of different classes, whilst it minimizes the distance between the face images of same class.

The fisher-face method an able discards some variations in lighting and facial expression by maintaining prominent features [11, 23, 93]

The use LDA on a set of face images which contains a set of classes to determine a single projection that maximizes the discrimination between them is defined [67] as below.

1. Separate a set of N face images $\{x1, x2, \ldots, xn\}$ into appropriate C class matrices $\{C1, C2, C3 \ldots Cn\}$ then the total mean μ is defined as:

$$\mu = \frac{1}{N}\sum_{i=1}^{N} x_i \qquad (4.15)$$

Where N is the number of face image

2. Define between-class scatter matrix (B_s)

$$B_s = \sum_{i=1}^{C} N_i(\mu_i - \mu)(\mu_i - \mu)^T \qquad (3.16)$$

Where C describes the number of face classes (individuals), N_i the number of faces in each face class, μ_i mean of face class and μ is the overall mean of all different face classes.

3. Within-class scatter matrix can be also defined as:

$$W_s = \sum_{i=1}^{C} \sum_{x_k \varepsilon\ x_i} N_i(x_k - \mu_i)(x_k - \mu_i)^T \qquad (3.17)$$

Where $N_i$the number of faces in each faces classes and $\mu_i$is the mean of a face class

4. Maximize the Fisher Discriminant ratio of between-class scatter matrix $B_s$of the projected sample and the within-class scatter matrixW_s. The Fisher Discriminant Criterion ratio defined as:

$$W_{max} = argmaxW\left(\frac{|W^T B_s W|}{|W^T W_s W|}\right) = \lceil_{123} \cdots {}_m\rceil \qquad (3.18)$$

Where $\{_i | i = 1,2,3, \ldots m\}$ is a set of generalized eigenvector of B_s and W_s corresponding to a set of decreasing generalized eigenvalue $\{\lambda_i |\ i = 1,2, \ldots m\}$ is defined as

$$B_{s\,i} = \lambda_i W_{s\,i}$$

Where the upper bound m is C-1 where C is the number of classes

For LDA approach, the same procedure as PCA is used to calculate the eigenface, but only N-C eigenvectors were retained for the need of dimensionality reduction. Then the Fisher linear discriminants will project a facial image into a reduced image space of *c-1* dimensions, in which the ratio of between-class scatter to within-class scatter is maximized for all *c* classes. Figure 5.16 shows the mean facescreated from three image datasets. Using LDA, the number of Fisherfaces found isanequal to a number of classes -1. Some of the Fisherfaces computed during our experiment are shown in Figure 5.17.

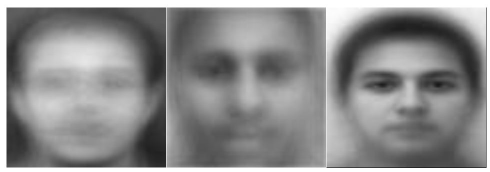


Figure 4.20 Mean Face (LDA) for FEI, Self-Prepared, and ORL databases respectively

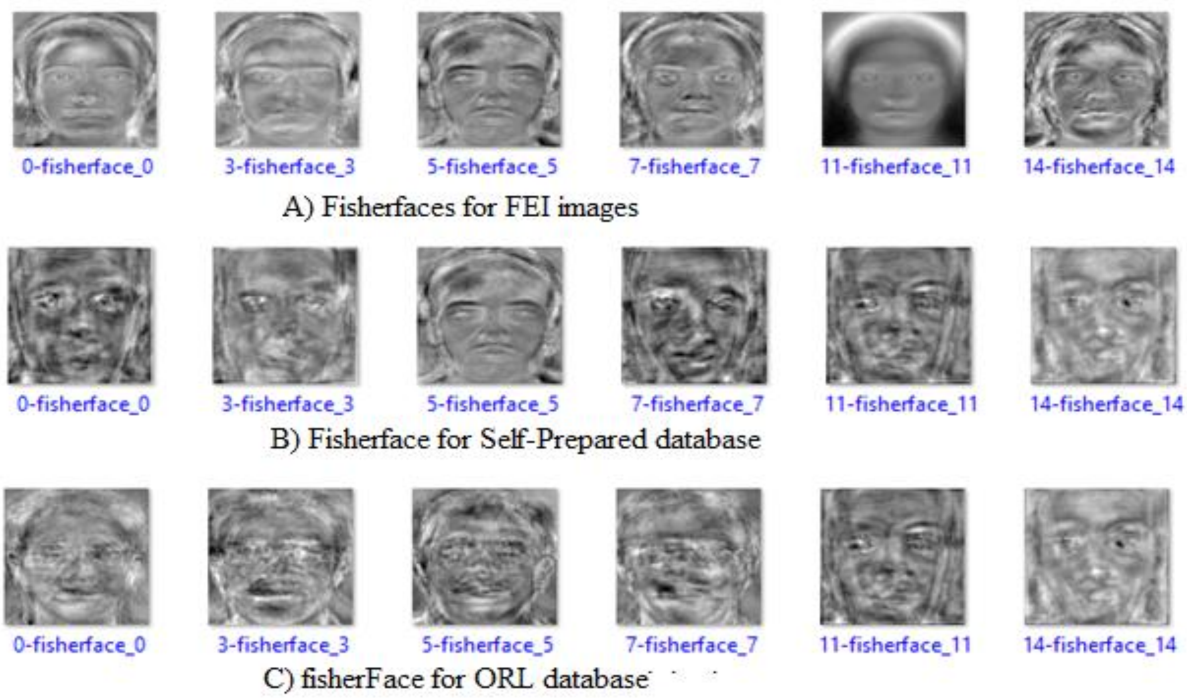


Figure 4.21 Fisherfaces Computed From FEI, Self-Prepared, And ORL respectively

As eigenface, all the fisherface images are ranked based their usefulness in characterizing the variation among the images. Thismeans animage with highest fishervalue is ranked at first position and the image with thelowest eigenvalue positioned at last.

4.7 Nearest NeighbourClassification

The nearest neighbor approach uses a distance similarity metric to identify a new face image by searching for the most similar vector in the training set to this new image's feature vector [57].Many research works have been shown various techniques to measure the distance between two images [7]. The Euclidean distance and the Mahalanobis distance are the most common nearest neighbor approaches used for similarity measure. In this study, we adapt the Euclidean distance measuring technique to compute the distance between the feature vector of each image in the testing set and each face class.According to Turk and Pentland [74] the Euclideandistance is the simplest method used to calculate the distance of the test image vector to the mean of each class of the training image vectors.The simplest method for determining which face class provides the best description of an input face image is to find the face class k that minimizes the distance. The test image, Γ, is projected into the face space to obtain a vector,**Ω** as:

$$\Omega = U^T(\Gamma - \Psi) \tag{3.19}$$

The distance of **Ω** to each face is called Euclidean distance and defined by

$$\mathcal{E}_k^2 = \left\| (\Omega - \Omega_k)^2 \right\| \tag{3.20}$$

Where k = 1, 2… M and$\Omega_k$is a vector describing the kthface class.

$$\mathcal{E}_k = \min\{\mathcal{E}_i < {}_i\}$$

We specify a threshold $_i$for each of the i = 1. . . g individuals. The image is classified as unknown if $\mathcal{E}_i \geq \theta_i \forall_i$= 1 . . . g. otherwise a face is classified as belonging to class k when the minimum $\mathcal{E}_k$is below some determined threshold$_k$ and the Euclidean distance $\mathcal{E}_k$is the smallest distance over all possible distances.

In this study, wedefine a high threshold value that all images will be classified as their nearest neighbour. The threshold we define in our experiment is θ_i=5000. This high threshold means that no images are rejected as unknown and each image is classified as its nearest neighbour.

CHAPTER FIVE

5. RESULT AND ANALYSIS

In the previous chapter, the requirement needed for personal identification systems were well described andthe development platform and tools werestated.We also defined a suitable face detection and recognition algorithm.We are now in aposition to evaluate it to see the performance the algorithm under various conditions.

Initially, the performance of Viola and Jones face detection algorithm was tested by comparing the number of faces detected via human face detection ability. The face detection experiment considers four distinct image dataset and showing theresult of all these sets. The first test is using well-known images taken from CMU MIT datasets. The other tests evaluate the system using LFW, FEI, and Self-prepared datasets. Each dataset is described in section 3.2. The performance of the overall datasets is tested by varying various parameters such as scale factor, and MinNeighbour.

For recognition purpose, we have used self-prepared, FEI and ORL datasets. All these datasets were derived from face images that are already detected by the Viola-Jones algorithm. The performance of these datasets was tested using both PCA and LDA face recognition algorithms.

5.1Face Detection Experiment

In the previous sections, we defined suitable face detection and recognition algorithms. We are now in a position to test it to see how it performs under varying condition. The experimentation process requires a lot of tasks.The OpenCV library which provides programs to train classifiers for face detection was used in this thesis. The training process has different steps as follow:

- Preparing datasets: this step related to collections of positive and negative sample datasets from well-known databases. Positive sample datasets are images that contain the objects of interest. In our case, positive sample images will contain faces that we want to detect. But, negative datasets contains another object out of theobject of interest such as background images and non-face samples.

- The collected sample imagesare divided into positive images containing anobject of interest for training, anegative image containing non-face object for training, positive images for testing, and negative image for testing.
- Training:OpenCV was used to apply theAdaBoost algorithm in haar cascade training. In this implementation, the haar cascade will be used in haar detection tool for object detection.

In total492 images from CMU MIT and self-prepared databases were contained 1095 faces.From the face inspection, only 1003 faces were actually detected by the algorithm with 25 false detections. In addition, false rejections were appeared due to an extreme rotation caused by the camera which took the face. For instance, one facein figure 5.1 is clearly visible but it has not been detected.Because the viola-jones algorithm is poor performs for thenon-frontal face.

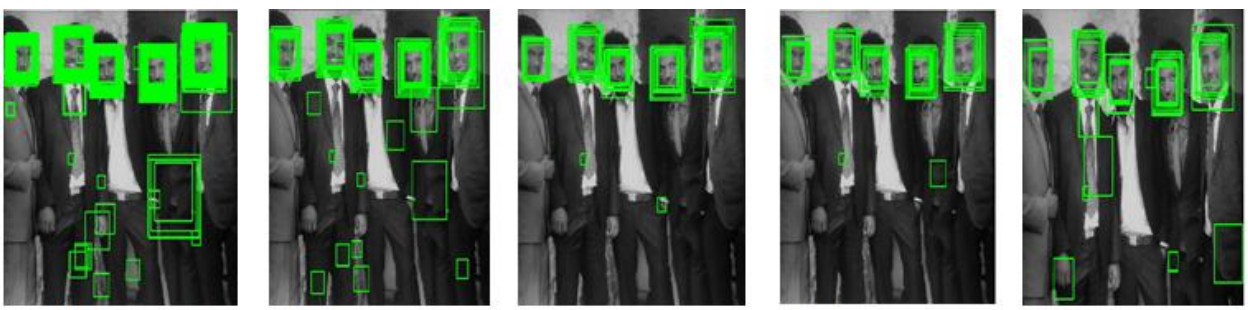
Figure 5.1 difficulty of viola-jones method for rotated face

Depend on the application perspective; we defined algorithm evaluation criteria which allow us to see the accuracy and performance of the detector. This process is mainly used by many researchers to evaluate their algorithm with respect to various test cases.In this study, the algorithm was evaluated using three different image databases which contain more images with variation in expressions, illumination, and pose. We also prepared our own additional datasets to further advance our insight about the behavior of the detector.

Our main intention in the face detection experiment is simply to train the viola-jones detector from the scratch and to examine the performance and accuracy of the algorithm. It is essential for system setup to adjust in which performance rates are to be expected. The OpenCV application interface provides different parameters which are necessary to evaluate the performance of the detector. The parameters we used in our experiments are scale factor, min Neighbor, minimum and maximum image size. By varying the parameter value each, the computational time, detection rate for different image database were computed and reported to evaluate the overall system accuracy

5.2.1Scale Factor &MinNeighbour

The scale factor and MinNeighbour are important parameters which were applied in our experiment to achieve the required accuracy of the detector. The scale factor was varied from 1.05 to 1.45 and applied on a set of positive and negative test images. The small scale factor value causes the detector to run slower than the one with higher scale factor value. But if the value is too high, it may reject or skip some faces from being detected.



at scale factor 1.05 | 1.15 | 1.25 | 1.35 | 1.45

Figure 5.2 face detection with number of haar detector at different scale factor

Figure 5.2shows that the images tested with smallest (1.05) scale factor generatea large number of false detection with many numbers of positive detections. A false detection rate and average time decreaseby increasing the scale factor. But this may not be always true due to unexpectedcondition occurred during detection time.

In figure 5.2we observe a number positive rectangles overlap each other on the face area after the viola-jones method has been trained. These many overlapped rectangles are merged into asingle or average rectangle by specifying min neighbor value. The Min Neighbor parameter values also allow us to eliminate false detected faces from detection result.

Figure 5.3 Sample Face Detection with Minimum Neighbor 1 and Scale Factor Varies From 1.05 To 1.45

The multiple detections in figure 5.2were merged to single detection in figure 5.3 by varying the minimum neighbor of the detector. In merging process, a set of detection rectangles that overlapped each other were grouped together to create an average rectangle. For instance, the minimum-neighbors value 4 indicated merging a group of four or more rectangles and discards groups with fewer rectangles. In addition, some false detection may appear around the face region of the testing image. Figure 5.4 indicates experiment result of the detector by varying the scale factor value to evaluate the average time required to detect a single image. The scale factor values were varied from 1.05 to 1.45 for all image databases.

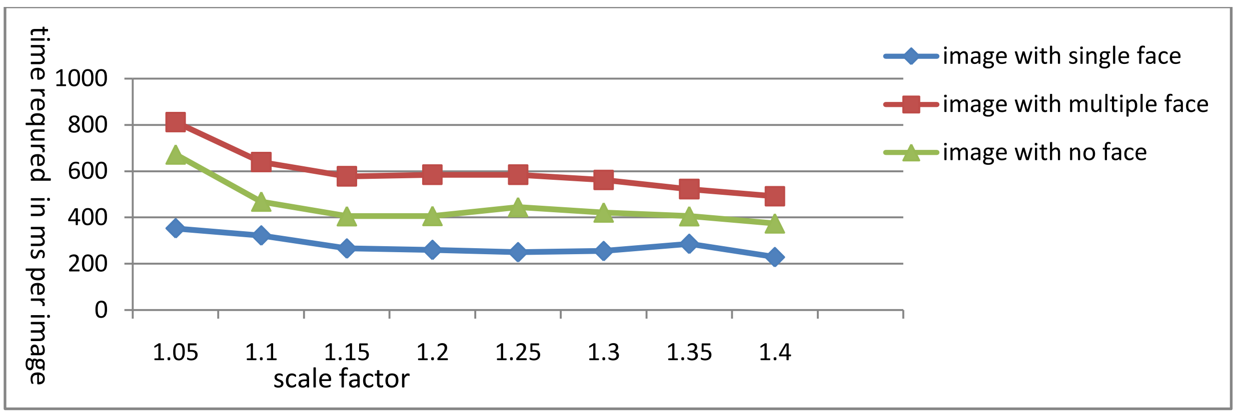


Figure 5.4 Average times required to detect single image

We alsotested the whole database images containing182,200, 150 and 2339 images sets collected from CMU MIT, FEI, self-prepared, LFW database see more detail in section 3.2. All the datasets were tested using similar methodology and compared each result. The experiment also evaluates the usefulness of using scale factor, minimum neighbor and detector size. Figure 5.5shows the time rate of the detector with scale factor and as scale factor increase from 1.05 to

1.45 the detection rate to increase. But due to some unpredicted defects, it may not be always true as seenbelow.

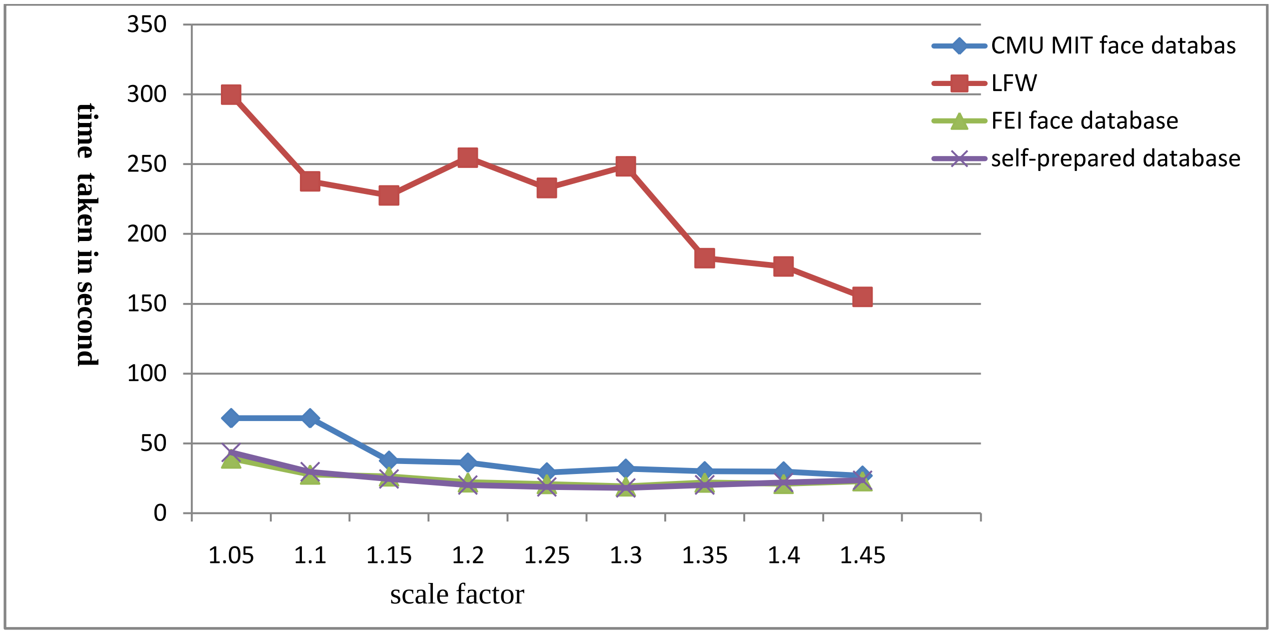


Figure 5.5 Average times required for each face dataset

The detector accuracy was evaluated on the whole dataset images rather than using small sample datasets. To perform a comparison between individual datasets, the false positive (FP), true positive (TP), and true negative detections were identified in each database and different parameters are taken into consideration. The parameters under consideration in this thesis are database name, the number of images in the database, the total number of faces available in the database, number of positive detected faces by the detector, number of false detection, the number of false rejection, the time taken to execute the algorithm, and accuracy rate of the detectors. The true detection rate, false rejection rate, and false detection rates are calculated according to the equation below.

$$true\ detection\ rate = \frac{number\ of\ correctly\ detected\ faces}{total\ number\ faces\ on\ the\ test\ image} \qquad (\ 4.1)$$

$$false\ detection\ rate = \frac{number\ false\ detections}{total\ number\ of\ faces\ on\ the\ test\ image} \qquad (4.2)$$

$$false\ rejection\ rate = \frac{total\ number\ of\ faces\ rejected\ by\ detector}{total\ faces\ on\ the\ test\ image} \qquad (4.3)$$

$$
\begin{aligned}
&total\ accuracy\ rate \\
&\qquad = true\ detection\ rate \\
&\qquad - (\ false\ detection\ rate + \ false\ rejection\ rate)\ (4.5)
\end{aligned}
$$

The accuracy of the detector varies with variation in scale factor and minimum neighbor. But the detector performs average performance at scale factor 1.15 and minimum neighbor 3 for all databases. All the false detected faces and false rejected faces are manually counted from each dataset and results were calculated as thetable below.

Table 5.1 overall faces detection experiment result

Face Database Names	Number Of sampled Images	Number of faces	Detected faces	False detected	False rejected	Detection rate
Labeled Faces in the Wild	2339	2339	2320	25	19	98.11%
FEI Face Database	200	200	200	0	0	100%
CMU MIT database	182	Around 615	545	19	70	85.52%
Self-prepared database	350	545	478	13	67	85.31%

5.2.1 Real-Time Face Detection Results

In addition, the performance of the Viola and Jones algorithm was tested directly using alive camera where the person to be detected was position in front of thecamera. The object frame size is at different scale depending on the distance between the camera and the person. The object sizes greatly reducedasthe distance far from the camera sensor, but that object has large size when close to the camera location. To see the effect of distance from thecamera, a set of tests were performed with minimum detection window size varying from 5x5 to maximum size 250x250 pixels.

Figure 5.6 distance-dependent scaling of the detection window

Figure 5.6shows the idea of distance-dependent scaling and the size of detector windowslightly decrease with increasing distance from thecamera.In this experiment, we perform a serious of tests cases by varying the distance between camera sensor and thesubjectto be detected.

Test Case1: subject 1 meter away from camera

An experiment was carried out by placing the subject at theposition of1meter away from the camera. With this distance, the face detector frame appearedon the video stream at a size of 91x91 pixels. The experiment was repeated using this condition for a number of peoples.

Table 5.2 face detection result at 1 meter

Total number of frame tested	True detection	False detection	False rejection	False positive in%	False rejection in %	True positive in %
40	37	4	3	10%	7.5%	92.5%

Table 5.2 shows a test result of theViola and Jones algorithm in real time scenario with variation subject distance from thecamera.The average face detection accuracy at 1-meter distance is 82.5% with 10% false detection and 7.5% false rejection rate.

Test Case2: subject 2-meter away from camera

The algorithm further evaluated at distance 2-meter away from the camera sensor. With this distance, the detector window appears on the subject at 50x50 pixel size.The experiment was repeated for 40 subjects using aforementioned condition and result score are described in table 5.3.

Table 5.3 face detection result at 2 meter

Total number of frame tested	True detection	False detection	False rejection	False detection in%	False rejection in %	True positive in %
40	34	4	6	10%	15%	85%

Table 5.3 shows that detection result of Viola and Jones algorithm at 2-meter distance. The overall detection accuracy is 75%. This indicates that performance decrease as thedistance between the object to be detected and camera sensor increase. In addition, the detector draws more rectangles per frame than in test case 1.

Test Case3: subject 3-meter away from camera

In this case, we also repeated the previous experiment (test case 2)by varying the distancebetween theobject being detected and the camera tothreemeters.The face detection algorithm also draws more rectangles per frame than in test case one and two.

Table 5.4 face detection result at 3 meter

Total number of frame tested	True detection	False detection	False rejection	False detection in%	False rejection in %	True positive in %
40	29	8	11	20%	27.5%	72.5%

Table 5.4 shows that detection result of viola and Jones algorithm at thethree-meter distance between object and camera. The overall detection accuracy is 52.5%. This indicates that performance greatly reduces as distance increase from the camera.

As we have observed from the result of three different test cases, we conclude that the viola-jones algorithm is effective for face detectionup to adistance of three-meter. The number of false detection and rejection increases as the distance goes from 1-meter to 3-meter. At the meter of four and five the false detection and rejection rate is greater than the true detection rate.

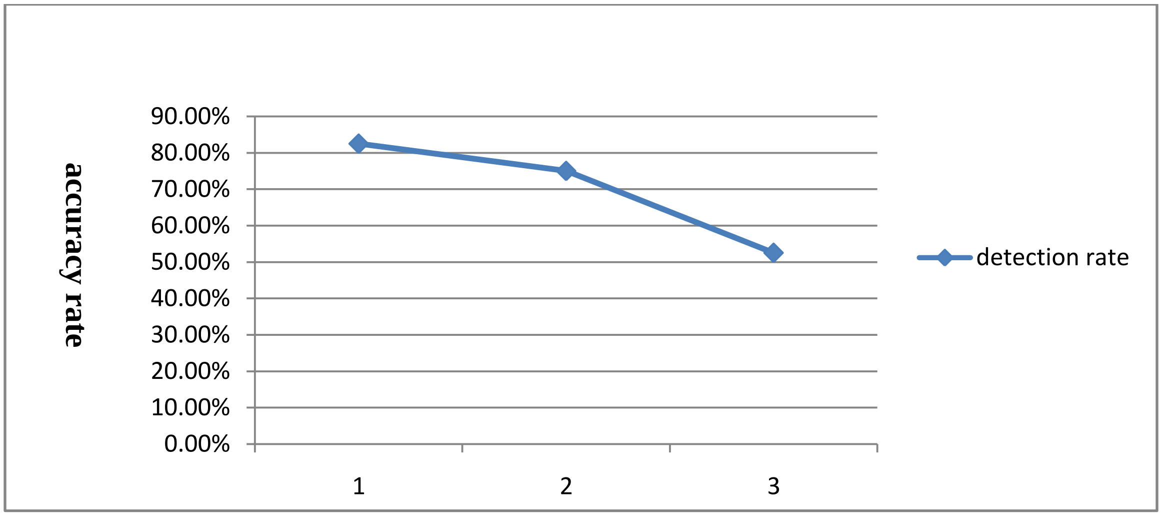


Figure 5.7 real-time face detection accuracy

The performance of viola-jones algorithm also decreases due to the pose caused by extremely rotation in the image capturing device. For example, the image in figure 5.1 clearly shows this situation. The image is clearly visible to everyone but it has not been detected due to therotation. Even the algorithm iteratively trains that image it cannot find the face.

In general, from the overall face detection experiments we can conclude that the viola-jones algorithm is a successful method for frontal faces, but difficult for non-frontal or rotated face. Since most of the training used for this experiment wasa frontal face with theunconstrained environment, it generates asuccessful result.

5.2PCA based Face Recognition Result

In the previous chapter, we have defined the basic idea of PCA and LDA face recognition methods; we are now in a position to conduct experiments to measure algorithm performance. In order to develop a coherent face recognition result, a source code was written using Javaprogramming with OpenCV 3.1.0 image processing Library file. The code covers all the steps defined in section 4.6.1 and examined each step defined.

Training sets

In order to see the performance of the recognizer, a training set of face image should be selected from various data sources. In this study, the recognition methods were implemented using ORL, FEI,and self-prepared datasets. M=5, 3, 1 images of each individual were chosen to form training sets of M=200, 120 and 100 images from ORL, Self-prepared and FEI databases respectively. Each image in training and testing sets were resized to dimension 128 x 128 pixels and the training image would be created with the unique name of the images desired with a single filename per person in alphabetical. This simplified the process of reading in the images, counting them, and most importantly, keeping track of which faces were matches.

Table 5.5 databases for recognition

Database name	**Number of images**	**No face per individual**	**Total training sets**	**Total testing sets**
ORL database	400	10	200	200
Self-prepared database	200	5	120	80
FEI face database	200	2	100	100

As seen in table 5.5, the ORL face database partitioned into a training set of 200 images and a test set of 200 images. Each set contained five face images per person for testing and five images for training. For the self-prepared database, three images per person were randomly chosen to produce a training set of 120 images. While the remaining 80 images were used to create a test set.

Table 5.6 image capturing condition

Training images				
Face type	**angle rotation**	**Facial expression**	**Gender/Age**	**Illumination variation**
Frontal	*yes*	Yes	Any	Yes
Testing images				
Frontal	*yes*	Yes	Any	Yes

As table 5.6 shows, the training image is frontal, with facial expression and illumination. It also has small angle variation without considering gender and age differences. In terms of ethnicity, black and white people from Africa, Asia and western are considered.

During ourexperimentation, we consider several variables that can either be varied or need to be kept constant during theimplementation of eigenface. These variables including the number of eigenface or fisherface, number of training samplesand testing samples, number of image per subject and Effectiveness of image normalization and masking.

5.2.1 Number of Eigenface

The first variable we considered in this experiment is determining the number of Eigenfaces to use in order to identify the faces. This is important to know how many eigenfaces we need to accurately identify face images.The aim of identifying the minimum eigenvectors with thehighest accuracy helps as to minimize the data storage and computing requirements of the method. Therefore it is better to minimize the number of eigenvectors taken whilst maximizing the recognition accuracy of the method.

During testing the number of eigenfaces, all other variables need to be constant. We consistently used the same training sets with the same image size. The only variable we need to vary is the number of eigenvectors.For this experiment, all the three image datasets were testedby varying numbers of eigenvectors toM = 15, 30, 45, and 60. Knowing the optimal value of M helps to minimize data storage and computational requirements. The accuracy rate for each database at the specified eigenvector can be computed usingtheformulabelow.

$$Accuracy\ Rate = \frac{Number\ of\ correctly\ classified\ images}{total\ number\ of\ image\ samples} \quad 5.1$$

5.2.1.1 Test result on FEI dataset

As shown in table 5.5, we used total 100faces for testing and 100 faces for training. Each individual person contributes one face image for testing and another one for training.An appropriate number of eigenvectors for both PCA and LDA part must be used to obtain better results. The performance of PCA and LDA methods were on eigenvector 15, 30, 45 and 60 for 1st configuration. The results obtained from the experiment aresummarizedin the table below.

Table 5.7

Table 5.7 face recognition result usingFEIdataset

Database Name	No eigenvectors	PCA			LDA		
		Correctly classified	Incorrectly classified	Accuracy In %	Correctly classified	Incorrectly classified	Accuracy In %
FEI	15	90	10	90%	81	19	81%
	30	91	9	91%	92	8	91%
	45	92	8	92%	93	7	93%
	60	91	9	91%	93	7	93%

The table displays the accuracy achieved during the PCA and LDAalgorithms testing. And the overall performance of the PCA and LDA methods at15 eigenvectors is 90% and 81% respectively. The performance increased as the number of eigenvector increases from 15 to 45. The recognition accuracy of both methods reaches a maximum number 92% and 93% respectively at anumber of eigenvector 45. The performance slightly begins to decreaseat60eigenvectorsfor PCA method but remain constant for LDA method. The comparison result of PCA and LDA were given in figure 5.9

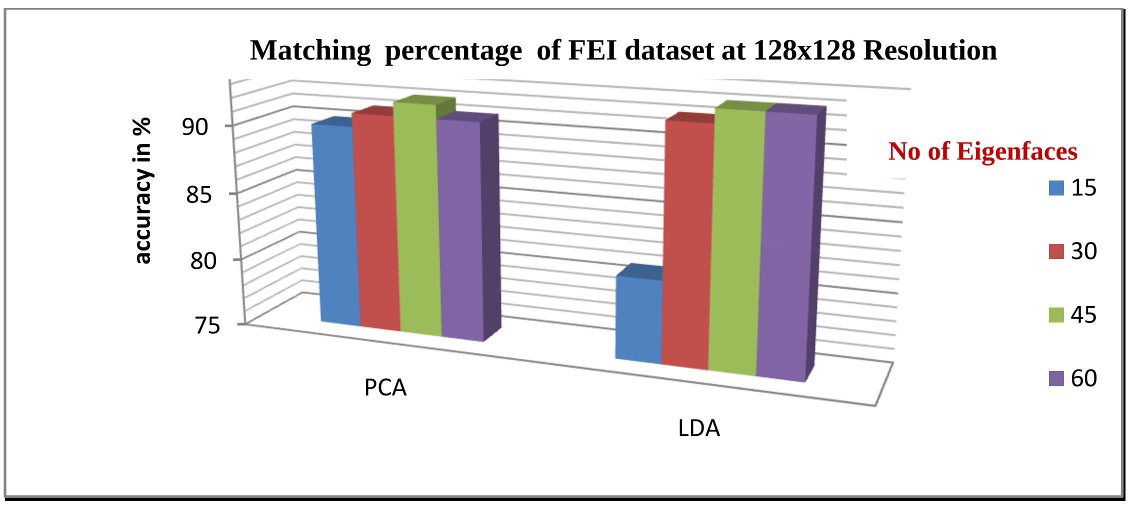


Figure 5.8 Comparison result of PCA and LDA on ORL database

5.2.1.2 Experimental result on ORL

Figure 5.9 Sample testing and training image from ORL dataset

Figure 5.9 shows sample images from ORL dataset. The ORL contains face images with different facial expressions, small angle variation and slightly illuminations variation images. For the experiment purpose, we randomly divide the whole set into training and testing as in figure 5.9. Anindividual person contributes 5 images for training and 5 images for testing. The first experiment was tried on resolution 128x128. As theprevious experiment on FEI dataset, anAppropriate number of eigenvectors for both PCA and LDA methods should be used to obtain better results. The results obtained from the experiment are summarized in table 5.7

Table 5.8Face recognition result using ORL dataset

Database Name	**No eigenvectors**	**PCA**			**LDA**		
		Correctly classified	**Incorrectly classified**	**Accuracy In %**	**Correctly classified**	**Incorrectly classified**	**Accuracy In %**
ORL	15	182	18	91%	167	33	83.5%
	30	185	15	92.5%	170	30	85%
	45	189	9	94.5%	180	20	90%
	60	189	9	94.5%	182	18	91%

As seen from the results of table 5.7, when we used 15 eigenvectors, the accuracy rate becomes 90% and 83.5% for both PCA and LDA methodsrespectively. When we increase the number of eigenvectors, the accuracy rate significantly increased. At eigenvectors 45and 60 the accuracy rate of PCA remainsconstant, while it slightly increased in LDA. According to the results shown above, the accuracy of both methods achieves ahigh result(94.5 and 91%) when using 60 eigenvectors. In general, from the experimental result observation, we conclude that PCA face recognition method outperforms the LDA face recognition method.

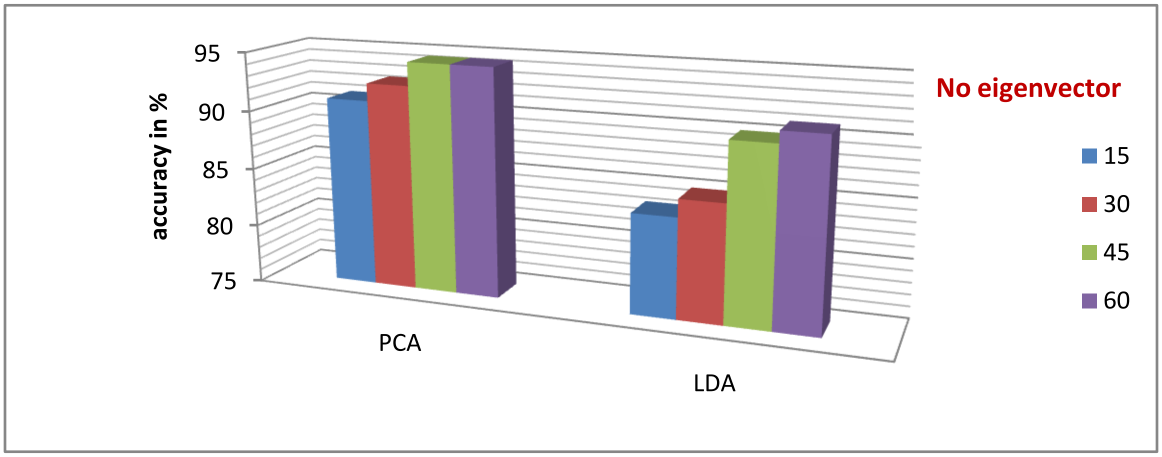


Figure 5.10 Comparison result of PCA and LDA using ORL dataset

5.2.1.3 Experimental result on self-prepared dataset

Figure 5.10 self-prepared dataset

The third experiment is conducted using the self-prepared datasets collected from 40 individuals. Like the above experiment, the whole datasets were divided into training and testing sets. Each individual person contributes three face images for training and two images for testing. The three images of each person in self-prepared dataset create total 120 training face images and use other 80 images as atesting set. Each image has asmall variation in pose, illumination,and facial expression. The testing result of theself-prepared dataset is summarized in the following table 5.11.

Table 5.9 recognition rate for self-prepared database

Database Name	No eigenvectors	PCA			LDA		
		Correctly classified	Incorrectly classified	Accuracy In %	Correctly classified	Incorrectly classified	Accuracy In %
Self-prepared dataset	15	71	9	87.75%	64	16	80%
	30	70	10	87.5%	65	15	81.25%
	45	68	12	85%	65	15	81.25%
	60	67	13	83.75%	65	15	81.25%

The table above displays the accuracy achieved during the PCA and LDA algorithms testing. The recognition accuracy of PCA algorithms reach a maximum number 87.5% when the number eigenvector used is 15.And the overall performance of the system decreases with increasing the number of eigenvectors for PCA method. In the LDA experiment, the recognition accuracy remain constant (81.5%) for eigenvector 30, 45, and 60. And the low accuracy is achieved at eigenvector 15 as shown in table 5.11.

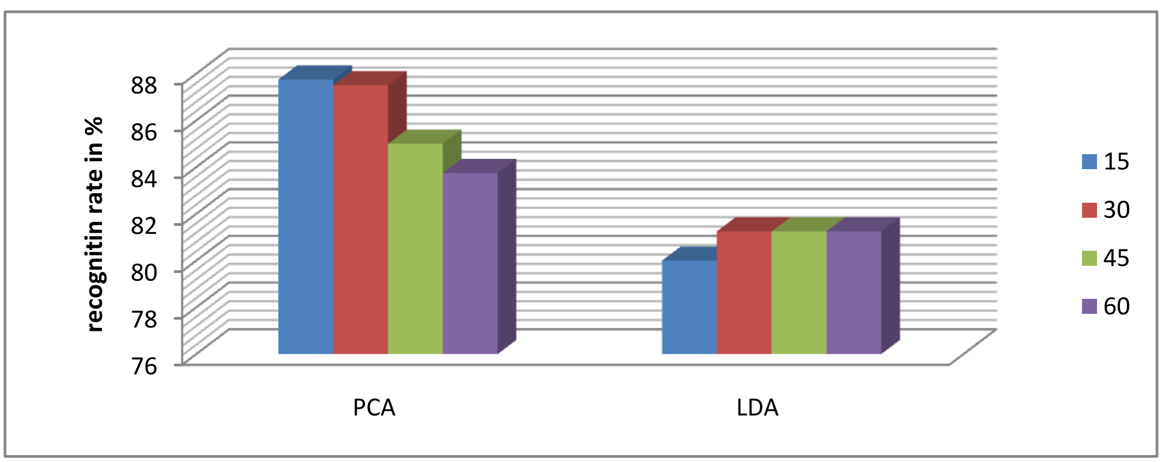


Figure 5.11 Comparisonresults of PCA and LDA on Self-prepared database

Another important evaluation method of PCA and LDA is the execution time. The execution time of the two methods was evaluated onan Intel i3 2.5 GHz and 4GB RAM personal computer. To compute the processing time, we run the code four times on each testing set. We then recorded the average execution time for each database as shown in thetable below.

Table 5.10 Computational times PCA and LDA on various databases

Database	PCA Execution time (Sec)	LDA Execution time (Sec)
FEI database	104.156	103.276
ORL	229.735	176.146
Self-prepared database	92.073	64.603

Table 5.10 shows that average execution time of the two algorithms using 15, 30, 45, and 60 number of eigenvectors. In both methods, anumber of eigenvector and computation time are directly related. As the number eigenvector increases, the computation time also increases. As we have shown in thetable above, the PCA method requires more computational timethan the LDA method while using the same evaluation methods.

5.2.2 Image Resolution Analysis

Face recognition systems can obtain promising results when using high resolution frontal images, but face recognition at a distance is still challenging. The face regions of images acquired at a distance are usually small and have low quality. Face recognition task can be more difficult in surveillance situation.

In this study, we conduct a series of experiments to determine an appropriate image resolution for further investigations regarding other image processing techniques.An experiment was conducted to examine the effects image resolution on the FEI, ORL and Self-prepared databases.

To see the effect of image resolution on recognition accuracy, an appropriate number of eigenvectors from the previous test result was usedfor both PCA and LDA methods.As we have observed in section 5.2.1, the PCA and LDA methods scores average recognition result at eigenvector 30 for all image samples. Therefore,we constantly used this eigenvectorto testand train the dataset samples with different resolution.All the other variables remain constant untilresolution testing finished.

In order to gain abetter understandingof whether image resizing is advantageous or not, the OpenCV image size function is used to change the resolution of the image in this experiment. We conduct several experiments and compared the accuracy of the PCA and LDA at different image resolution. The images resolution we created for this experiment are: 10x10, 20x20, 40x40, 60x60, 80x80, 128x128, and 150x150 shown in figure below.

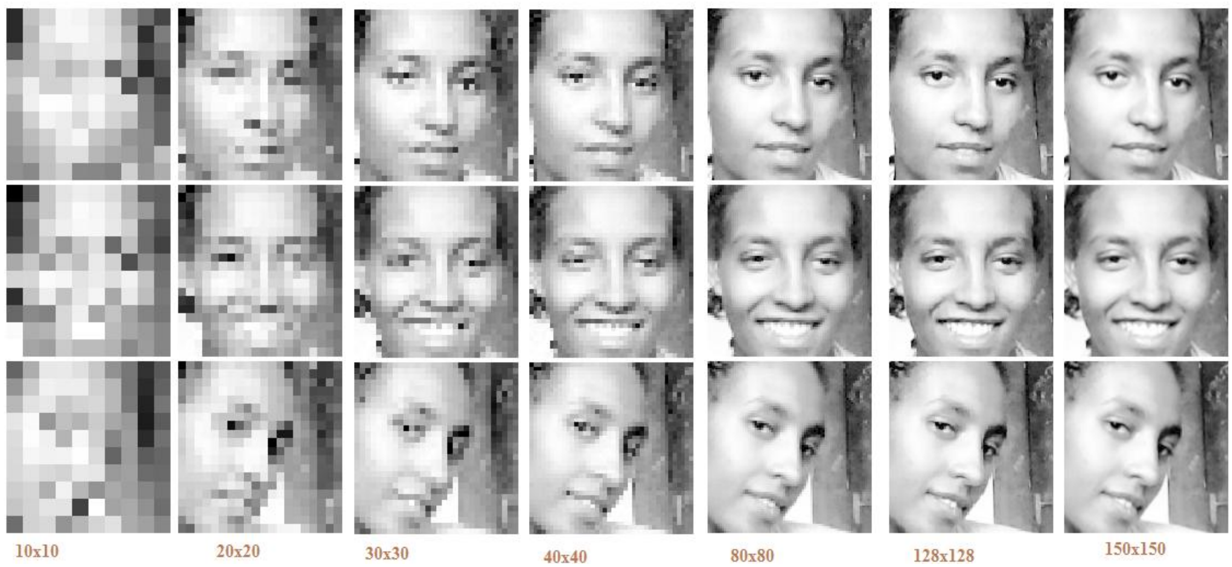
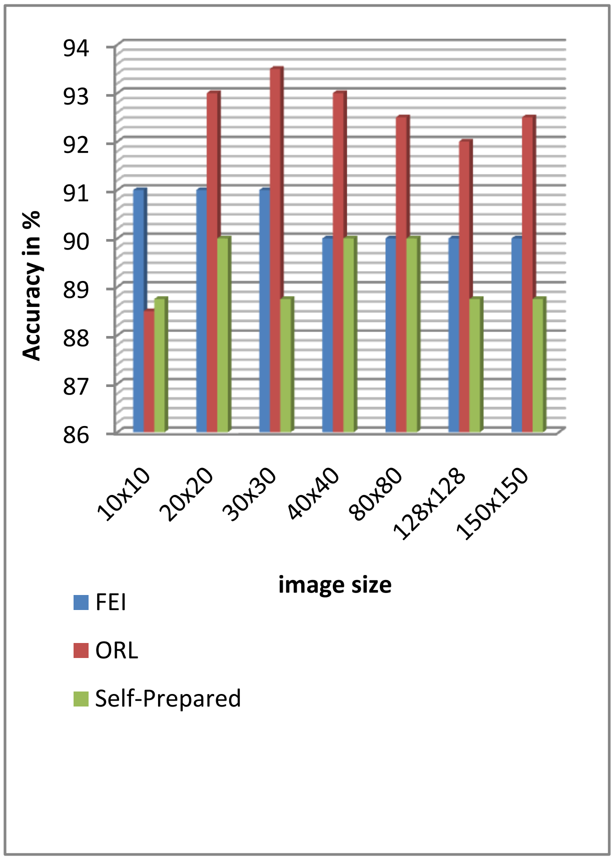
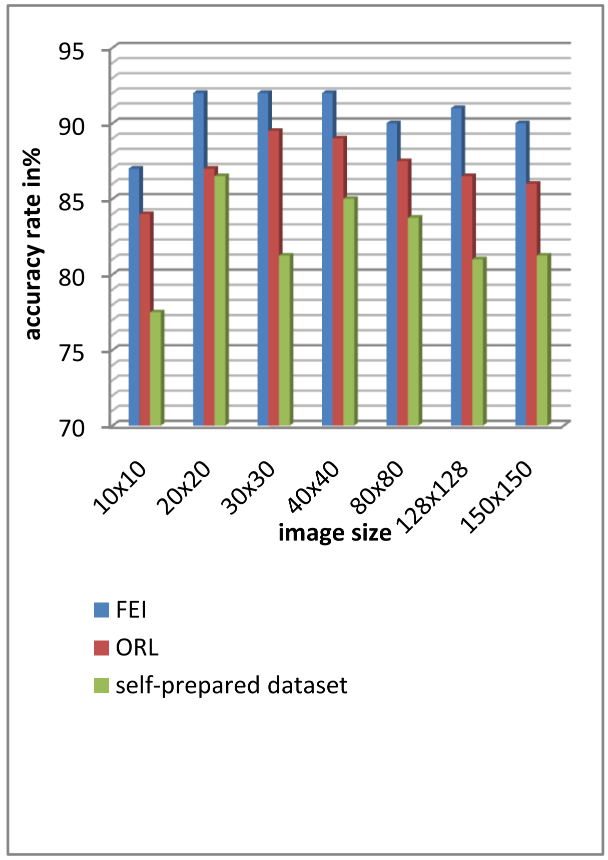


Figure 5.11 self-prepared sample images with different resolution

The recognition rate of the two methods for FEI, ORL, and self-prepared datasets using different image resolution can be shown in Figure 5.13.





a) PCA b) LDA

Figure 5.12The performance of PCA and LDA with different image size

We compared the performance of PCA and LDA using differentimage resolution with the same number of eigenvectors for the three datasets.

Figure 5.13a showed that the recognition rate of PCAis better or 92% when using image resolution 10x10, 20x20, and 30x30 for FEI datasets. The recognition performance drops to 90% as the image size becomes larger than 30 x 30 in figure 5.13a.In addition, the highest percent accuracy was a 93.5% achieved at 30x30 pixels in ORL dataset. The recognition rate decreases a bit as resolution increases to 128x128. In the self-prepared dataset a 90% recognition accuracy is achieved at image resolution 20x20,40x40,and 80x80 while the remain image size generates 88.7% accuracy.

Figure 5.13b shows the accuracy achieved during the LDA testing. And a higher recognition achieves when the image resolution is 30 × 30 or 40 × 40 for both the FEI and ORL datasets. The accuracy reduces as the resolution increase from 40x40 to 150x150 for ORL datasetwhile agradual decrease appears from 40x40 to 10x10.In self-prepared dataset tests, the highest recognition accuracy we achieved is about 89.5% when the image resolution is 30x30. But, a higher error rate occurs at 10x10 image resolution.

In general, at lower image resolution the accuracy rate becomes less. PCA performance decreases slightly for both ORL and Self-prepared datasets but remains constant for image resolution less than 30x30 and LDA performance becomes higher at resolution 30x30 for both ORL and FEI datasets. A gradual decrease occurredwhen image sizes are larger 30x30 than pixels in ORL dataset.Based on the test result in figure 5.13, we can conclude that the PCA is less sensitive to image resolution variations than LDA. so, the average performance of PCA is better than LDA.

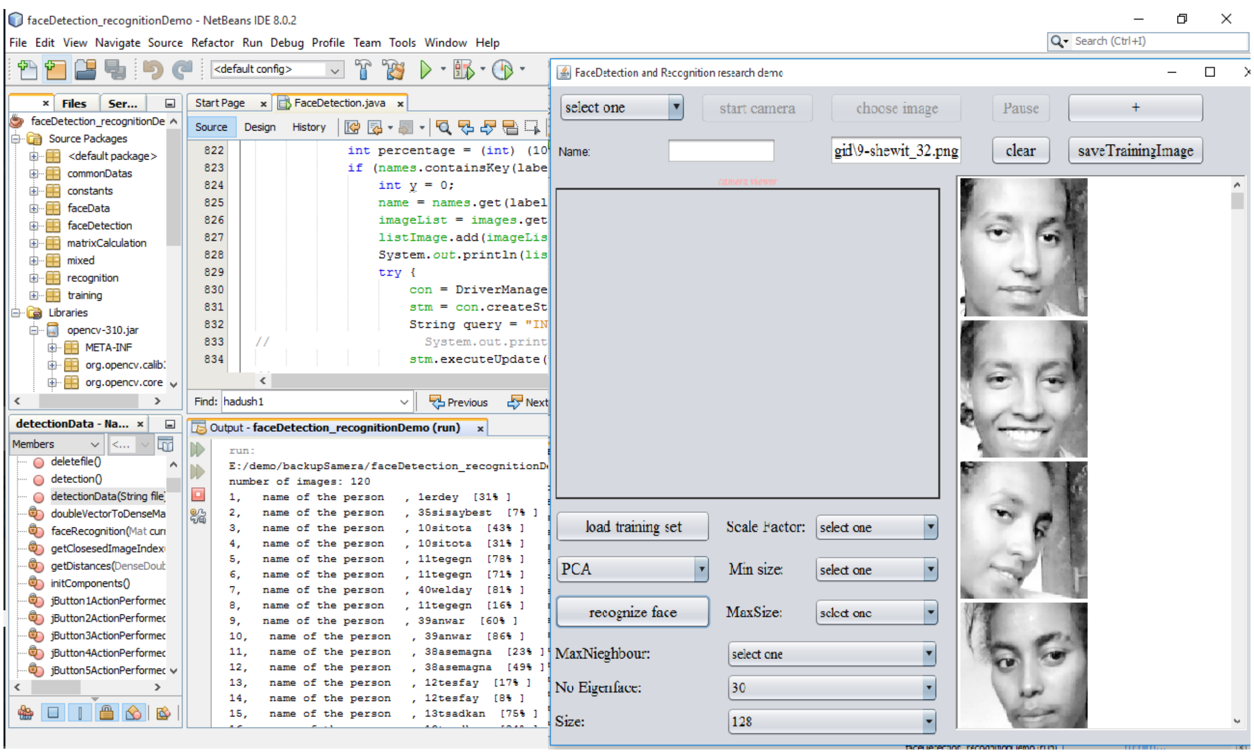


Figure 5.13 face recognition snapshot without masking

5.2.3 FaceMasking Analysis

In order to reduce image noise at the corner of the image, we implement elliptical masking technique. This removes out features such as hair, ear, and background that can influence face variation. To see the effectiveness of elliptical masking on face recognition algorithm, one successful image resolution from the previous test was used 128 x 128 pixels. In addition, a successful number eigenvector or 30 from theprevious test was used for all datasets. By taking the number of eigenface and image resolution the constant, the previous experiments were repeated through Appling elliptical masking technique. This is due to the reason that the PCA and LDA approaches are unable to thedifferential between images noise at thecorner of images, hair, and facial features, therefore these misinterpreted as aface image [101].Duringtraining, if the corner background and hairs are not removed itbecomes a principal component and describes the similarity of a data set. Table 5.12 shows that recognition result of PCA and LDA method when applying elliptical masking on the three datasets.

Table 5.11 face recognition accuracy on masked image

Database Name	**PCA**			**LDA**		
	Correctly classified	**Incorrectly classified**	**Accuracy In %**	**Correctly classified**	**Incorrectly classified**	**Accuracy In %**
FEI	95	5	95%	96	4	96%
ORL	182	18	91%	169	31	86.25%
Self-prepared	73	7	91.25%	67	13	83.75%

Table 5.11 shows that recognition result of PCA and LDA methods on theelliptical masked image. The overall recognition accuracy of PCA and LDA on FEI dataset with elliptical masking is 95% and 96% respectively. This indicates that performance improvement is also achieved than animagewithout elliptical masking. The other two databases also achieved agood result. But, the algorithms still generate better result without a mask for the corners of the image as shown in figure 5.13.

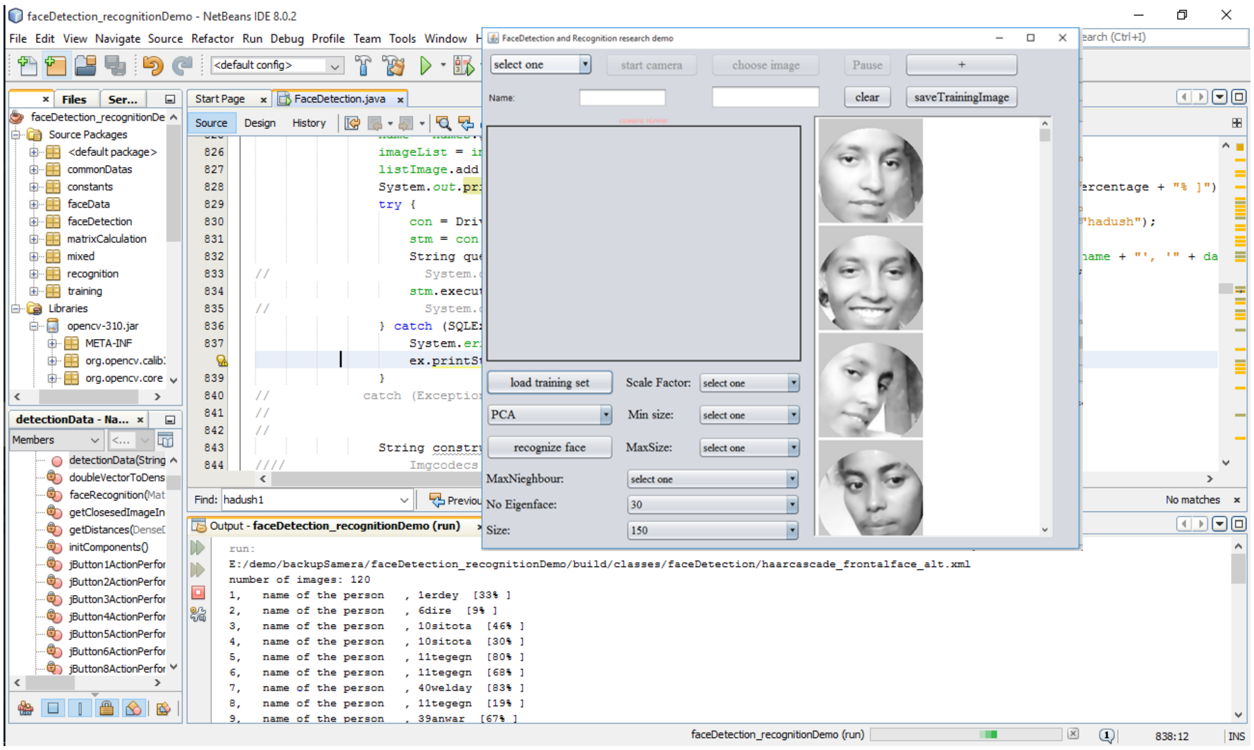


Figure 5.14 face recognition snapshot with elliptical masking

CHAPTER SIX

6. CONCLUSION AND RECOMMENDATION

This chapter presents the conclusions drawn from the findings of the experiment and the researcher's recommendations on further actions that can be taken, future research areas and the contribution of the work.

6.1 Conclusion

In this thesis, we have studied face recognition in real-timeand non-real time environment. The overall study consists six main chapters. The first chapter focuseson clarifying research problems, research background, research objective, research scope,andsignificance. The second chapter clarifies what other researchers have done in the past few years. In the third chapter, appropriate research methodologies have been described in detail. The fourth chapter discusses the proposed face recognition pipelines. It comprises three basic parts; the first part is face detection, the viola and Jones face detection method available in OpenCV class library has been implemented. In the second part, image preprocessing is applied to decrease the light variation between the testing set and training set. Moreover, the image resizing, image filtering and masking technique have been applied at this stage. The thirdpart is face recognition using principal component analysis and linear discriminate analysis. The fifth chapter is the experimental result and analysis.

In this study, we developed a prototype for detection and face recognition. The face detection prototype was developed by using Haar-like features and AdaBoost learning algorithm. The performance of the face detection was evaluated using images with adifferent scale factor, MinNeighbour, frame size and different distance.We have also compared the algorithm performance by evaluating its performance on three standard face databasesand one self-prepared database.According to the experiment result in section 5.1, we conclude that viola and Jones face detection method is anefficientalgorithm in both real-time and non-real-time environment.It achieves good accuracy for thefrontal face. But its performance reduces as the distance between thecamera and the object is high. Moreover, thehigh angle between the object and camera can influence the performance of thedetector.

In the second experiment, the possibility of the face recognizer in real-time and non-real-time has been investigated.We began by exploring the eigenface method of face recognition, implementing a face recognition system using image pre-processing techniques to produce a high-level accuracy. The preprocessing techniques we have applied in this research such as histogram equalization, bilateral filter, and image masking. Majority images used in this experiment are collected from the standard databases. The experiment showed that image that preprocessing techniques could greatly reduce error rates. The experiment resultsin three different databases produce an accuracy rate of 95%, 91%, and 91.25% respectively. Moreover, the accuracy of the algorithm was evaluated using the for mentioned image datasets in relation to various parameters such as anumber of theeigenvector, image resolution.

Another well-known face recognition method which has been studied in this study is LDA. Like the experiment using PCA or eigenface method, the face recognition experiment is performed using FEI, ORL, and self-prepared dataset, such thatboth the training and test sets are represented the same capture conditions.To use the fisherface method in face recognition, the training set should be adequate enough to represent the expected application data. Preparing such training set significantly increases the performance of the method.We tested the accuracy of the method using the same testing condition and preprocessing techniques as previous experiments, producing accuracy rate of 96%, 86.25%, 83.75% for the three different database using masking techniques. We also use the same evaluation criteria such as anumber of eigenvectors, animage resolutionas anexperiment in PCA and we achieved asatisfactory result.We compared the performance of PCA and LDA face recognition methods in detail in section 5.2.From the result of various tests we conclude the performance of LDA generateshigher recognition than PCA on FEI face database. however, the recognition PCA becomes higher for the remain two face databases. We have also made a thorough comparison of the algorithms by evaluating their performances on four standard face databases.According to the test result generated in section 5.2, the FEI database achieves abetter result in all evaluationcriteria we have used while the self-prepared database generates satisfactory result compared to another database. Thecomparison utilized as evidence to select the best method and database for farther investigation.

Contribution of the work

In order to achieve the objective of the research, an experimental testbed was designed and face detection and recognition prototype were developed. The prototypes aim to find a solution for the research question in section 1.3. To answer the research question1 in section 1.3, various face detection and recognition methods were described in the literature review chapter. And viola and Jones face detection methodwas selected for face detection purpose.Wealso use principal component analysis (PCA) and linear discriminant analysis (LDA) for the purpose of face recognition due to the reason that both PCA and LDA supports multi-input image. it also minimize data storage and computational requirements

To answer the second research question in section 1.3, we applied various preprocessing techniques such as Histogram equalization, bilateral filter, image masking, and image resizing techniques.

To validate theaforementioned research questions we developed two type prototypes using java programming language with the help of OpenCV library.The result shows that a significant improvement is achieved by applying various image preprocessing techniques. Moreover, Comparative analysis of PCA and LDA face recognition methods were done.

6.2 Future Work

Based on the experimental results and from the point view of this study, an attempt was made to focus on investigating the possibility of developing, face detection and recognition system for personal identification. Depending on findings and challenges facing, the development followings are the possibilities that should have to be done for the future in order to increase the performance of the recognizer.

As we describe in chapter one, there is no a single face recognition method that satisfies 100% in all circumstances, therefore in this work, an attempt has made on developing and enhancing face detection and recognition systems using various datasets . But it does not mean that the data set is sufficient, therefore in the future researchers who work on this area have to increase the size of the data set, doing this helps on improving the recognizer accuracy and even to ensure the applicability of face detection and recognition. Since, it is difficult to use face recognition with low accuracy in a real world.

In this study, the experiment was conducted with using PCA and LDA with Histogram equalization, bilateral filter, image masking, and image resizing techniques in order to remove image noises that degrade the performance of the algorithm. For future, the system has to be examined with different smoothing techniques to improve the recognizer accuracy.

Moreover, as we described before the experiments were performed using laptop camera and USB camera, therefore for future this should be extended by using different cameras such as IP camera, dynamic vision sensor etc. moreover, various lighting condition, age, and large pose variation should be considered.

References

[1] “Real Time Multiple Face Recognition Security System (Rtm-Fs)” Retrieved from https://www.researchgate.net/ on April 18, 2017

[2] Yogesh, “Automated face detection using color based segmentation & face recognition using eign-Face”, june 2012.

[3]. Arpita Patra, “Development of efficient methods for face recognition and multimodal biometry”MS-Thesis, 2006

[4] Sadi Vural, “Face recognition by using hybrid-holistic methods for outdoor surveillance systems” March2011.

[5] Kitili Jackson Mwendwa, “Automated Attendance Machine Using FacesDetection”, 2016

[6] “Perception and ComputerVision”

[7] Andrew Mullen, “Real time face matching with multiple cameras using principal component analysis”, Rochester Institute of Technology RIT Scholar Works,6-2006.

[8] Rabia Jafri, “Fusion of Face and Gait for Human Recognition” Athens, Georgia 2008

[9] Kongens Lyngby, “Face Recognition”,Master Thesis IMM-Thesis,2005.

[10] G. Finlayson, S. Hordley, G. Schaefer, and G. Y. Tian, “Illuminant and device invariant colour using histogram equalization”, Pattern Recognition, 38, 2005.

[11] Dhafer Ghani Honi, “A Comparative study of face Detection and Recognition Techniques”Computer Science (2013-2014

[12] Amir Faizi, “Robust Face Detection Using Template Matching Algorithm “, 2008.

[13] Wei-Lun Chao, “Face Recognition”, GICE, National Taiwan University

[14]Magomelo Munyaradzi, Mavhemwa Prudence, Mukabeta Tarirayi,“Use of Facial Recognition for Data Personalisation in Customer Relationship Management (Crm): Case of Great Zimbabwe Hotel” Aug 2014.

[15] Nancy Flores-Cuautle, “System for facedetection on a mobilephone using Javatechnology”, November 2007.

[16] Hiyam Hatem, Zou Beiji and Raed Majeed1hiamhatim 2005@yahoo.com,bjzou@vip.163.com, raed.m.muttasher@gmail.com, “A Survey of Feature Base Methods for Human Face Detection” .

[17] Kavi Dilip Pandya, “Face Detection – A Literature Survey “, 2015.

[18] Mrs. Sunita Roy, Mr. Sudipta Roy, Prof. Samir K. Bandyopadhyay “A Tutorial Review on Face Detection”

[19] Rainer Lienhart and Jochen Maydt, “An Extended Set of Haar-like Features for Rapid Object Detection“ Intel Labs, Intel Corporation, Santa Clara, CA 95052, USA Rainer.Lienhart@intel.com

[20] Avleen Bansal,”A Literature Review on Face Recognition System”, Department of Computer Science,2016.

[21] Muhammad Naeem, Imran Qureshi and Faisal Azam, “Face Recognition Techniques and Approaches: A Survey”,2015.

[22] Ing. Jiří Brázdil, “The comparison of face databases free for research purposes” Department of Informatics, Faculty of Business and Economics, Mendel University in Brno, xbrazdi1@node.mendelu.cz

[23] S Tewart Tseng,” Comparison of Holistic and Feature Based Approaches to Face Recognition” 10th of July 2003.

[24] Lei Guan “Face Recognition with Visible and Thermal IR Images” December 2009.

[25] Wei Cui, “A Scheme of human face recognition in complex environment”, school of computer and mathematics science,2014.

[26] Ján Voš˘cek Brno, “Identity verification based onePassports”Master Thesis, 2014.

[27] Fares Jalled and Ilia Voronkov , “Object Detection Using Image Processing” Moscow Institute of Physics & Technology, Department of Radio Engineering & Cybernetics.

[28] Theo Ephraim and Tristan Himmelman, “Optimizing Viola-Jones Face Detection for Use in Webcams”

[29] Wan Najwa Binti Wan ISMAIL “Object Detection System Using Haar-Classifier”, 2009.

[30] David G. Curry, Gary Martinsen, and Darrel G. Hopper,“Capability of the human visual system”

[31] Tang Ho-Man, Chinese University of Hong Kong “Face Recognition Committee Machine: Methodology, Experiments and a System Application”, July 2003.

[32] Corey A. Ciocchetti,”The Eavesdropping Employer: A Twenty-First Century Framework for Employee Monitoring”

[33] Anil K. Jain, Arun Ross and Salil Prabhakar, “An Introduction to Biometric Recognition”, 2014.

[34]. Anil K. Jain, Arun Ross, and Salil Prabhakar, "An Introduction to Biometric Recognition"

[35]. Sandra Maestre Sean Nichols, "Dna Biometrics"

[36]. Alina Klokova, "Comparison of Various Biometric Methods"

[37]. Penny Khaw, SANS Security Essentials (GSEC) Practical "Iris Recognition Technology for Improved Authentication"

[38]. Libor Masek, "Recognition of Human Iris Patterns for Biometric Identification"

[39]. Aly I. Desoky, Hesham A. Ali, and Nahla B. Abdel-Hamid, "Enhancing iris recognition system performance using templates fusion"

[40]. Wildes R, Asmuth J, Green G, Hsu S, Kolczynski R, Matey "A machine-vision system for iris recognition"

[41]. Divid lin,"A survey of image-based biometric identification methods: Face, finger print, iris, and others"

[42]. Shrutika Deokar, Sudeep Talele," Literature Survey of Biometric Recognition Systems"

[44]. "Biometrics and StandardITU-T Technology Watch Report "ITU-T, 2009.

[45]. Siddhesh Angle, Reema Bhagtani, Hemali Chhed"BIOMETRICS: A Further Echelon Of Security"

[46]. S. Asha and C. Chellappan, "Biometrics: An Overview of the Technology, Issues,and Applications"

[47]. Dipti Verma, Sipi Dubey, "static signature recognition system for userauthentication based two level cog, Houghtransform and neural network",2013.

[48]. Stephen J. Elliott, Ph.D. and Adam R. Hunt, "The Challenge of Forgeries and Perception of Dynamic Signature Verification"

[49]. H B Kekre and V A Bharadi, "Gabor Filter Based Feature Vector for Dynamic Signature Recognition"

[50]. Unsang Park, "face recognition: face in video, age invariance, and facial marks", 2009

[51]. Andrew W. senior and Ruud M. bolle, "face recognition and its applications"

[52]. Swathi Rajashekar,"Composite Feature-Based Face Detection Using Skin Color Modeling and SVM Classification"

[53]. Bhushan Lal Banchhor1, Mrs. Tripti Sharma2,"Hybrid Approach for Face Detection Using Skin Color Based Segmentation and Edge Detection"

[54]. Jagdish Prasad Goswami, Preetam Kr. Chourasiya, Nipendra Singh Chauhan, “Face Detection using Color based Segmentation and Edge Detection”.

[55]. Swathi Rajashekar, “Composite Feature-Based Face Detection Using Skin Color Modeling and SVM Classification”,2012.

[56]. Erik Hjelm˚as and Boon Kee Low, “Face Detection: A Survey”,2001.

[57]. Lauren Barker, “Face Recognition”,April 2011.

[58]. O.H. Boyers, “An Evaluation of Detection and Recognitin Algorithms to Implement Autonomous Target Tracking With A Quadrotor”, 2013

[59]. Rafael Osorio, “Ball Detection via Machine Learning”

[60]. Julien Meynet, , “Fast Face Detection Using”, July 2003

[61]. Yasaman Heydarzadeh and Abolfazl Toroghi Haghighat, “An Efficient Face Detection Method Using Adaboost and Facial Parts”

[62] Anshuman Prakash and Manoj Kumar Tewari “Study of Different Algorithms for Face Recognition”

[63].Omaima N. A. AL-Allaf, “Review of Face Detection Systems Based Artificial Neural Networks Algorithms”, Faculty of Sciences & IT, Al-Zaytoonah University of Jordan, February 2014

[64]. Qasim Hasan masher Al-shebani, “Embedded door access control system based on face recognition”,2014.

[65]. Thomas David Heseltine, “Face Recognition:Two-Dimensional andThree-Dimensional Techniques “, University of YorkDepartment of Computer Science.

[66].Gyasi Silas Baah “Face Recognition Using Principal Component Analysis”

[67]. Justin Nicholas Worsey, “Face recognition in an unconstrained environment for monitoring student attendance” July 2016.

[68]. Alice J. O’Toole, Fang Jiang, Dana Roark and Hervé Abdi “Predicting Human Performance for Face Recognition”

[69]. Martin Lades, Jan C. Vorbruggen, Joachim Buhmann, Jorg Lange, Christoph v.d. Malsburg, Rolf P. Wurtz, and Wolfgang Konen “Distortion Invariant Object Recognition in the Dynamic Link Architecture”

[70]. R. Brunelli and T. Poggio “Face recognition feature versus templates”

[71]. V.V. Starovoitov, D.I Samal, and D.V. Briliuk “Three Approaches for Face Recognition”,2002.
[72]. Alan L. Yuille, Peter W. Hallinan, And David S. Cohen, “Feature extraction from faces using deformable templates”
[73]. Aditya Wikan Mahastama, “Computer Vision “retrieved on January 19 2017 from http://lecturer.ukdw.ac.id/~mahas/dossier/
[74]. Matthew turk and alexpentland “Eigenface for recognition”
[75]. Peng Peng, Waterloo, Ontario, Canada, “A Software Framework for PCA-based Face Recognition”, 2016.
[76]. Abhishek Singhand Saurabh Kumar, “Face Recognition Using PCAand Eigen Face Approach”
[77].Anshita Agrawal,**“**User Authentication Mechanisms on Android”,2013.
[78]. Proyecto Finde Carrera,”Face Recognition Algorithms”, 2010.
[79]. Achim Sanjay Manikarnika, “General Face Recognition System”,2006.
[80]. Wei Zhang, hangwe@eecs.oregonstate.edu “Constellation Models for Recognition of Generic Objects” School of Electrical Engineering and Computer Science Oregon State University
[81]. M.C. Burly, T.K. Leungz, and P. Perona “Face Localization via Shape Statistics”, California Institute of Technology, 116-81, Pasadena, CA 91125, USA.
[82]. Reda Shbib and Shikun Zhou “Facial Expression Analysis using Active Shape Model”, School of Engineering, University of Portsmouth, United Kingdom
[83]. Utsav Prabh and Keshav Seshadri ” Facial Recognition Using Active Shape Models, Local Patches and Support Vector Machines” ECE Department Carnegie Mellon University 5000 Forbes Avenue Pittsburgh, PA-15213
[84]. Gonzalo Lopez Lillo, Barcelona, “Facial Landmark Detection using Active Shape Models”,October 2014
[85]. Rowley, Baluja, and Kanade, “Neural Network-Based Face Detection” School of Computer Science, Carnegie Mellon University, Pittsburgh, January 1998
[86] Phil Brimblecombe, “Face Detection using Neural Networks” Meng Electronic Engineering School of Electronics and Physical Sciences

[87]. Assistant Professor Omaima N. A. AL-Allaf " review of face detection systems based artificial neural networks algorithms " Faculty of Sciences & IT, Al-Zaytoonah University of Jordan, P.O. Box130, Amman, (11733), Jordan

[88]. Sinan Naji, Roziati Zainuddin, Hamid A. Jallb1, Masoud Abou Zaid, and Amar Eldouber "Neural Network-Based Face Detection with Partial Face Pattern" Faculty of Computer Science and Information Technology, University of Malaya, Kuala Lumpur, Malaysia and Faculty of Education, Al-fatah University, Tripoli, Libya

[89]. LinLin Shen, "Recognizing Faces --- An Approach Based on Gabor",July 2005.

[90] Stanley Michael Bileschi "Advances in Component-based Face Detection "Massachusetts Institute of Technology 2003.

[91]. Henry Schneiderman, "A Statistical Approach to 3D Object Detection Applied to Faces and Cars"CMU-RI-TR-00-06 and Robotics Institute Carnegie Mellon University Pittsburgh, May 10, 2000

[92]. Edgar Osuna, Rob ert Freund, Federico Giros "Training Support Vector Machines: an Application to Face Detection" Massachusetts Institute of Technology, Cam bridge, MA, 02139, U.S.A.

[93]. O.H. Boyers, "An Evaluation of Detection and Recognition Algorithms to Implement Autonomous Target Tracking With A Quadrotor", Grahamstown, South Africa November 2013

[94]. Pallabi parveen and bhavani thuraisingham "Face recognition using various classifiers; artificial neural networks, linear discriminant, and principle component analysis pxp013300@utdallas. Edu, bahavani, thuraisingham@utdallas

[95]. V. S□truc, F. Mihelic□ and N. Paves□ic□ , "Face authentication using a hybrid approach" Faculty of Electrical Engineering, University of Ljubljana, Trz□as□ka 25, SI-1000 Ljubljana, Slovenia

[96]. Steve Lawrence, C. Lee Giles, Ah Chung Tso, Andrew D. Back "Face Recognition: A Hybrid Neural Network Approach" NEC Research Institute, 4 Independence Way, Princeton

[97]. Weihao Gao, "Face Recognition Application Based on Embedded System", Department of Electrical Engineering and Computer Science CASE Western Reserve University.

[98]. Qasim hassen mezher Al-Shebani, "Embedded access control system based on face recognition",University of Wollongong, 2014.

[99]. Andrew Enughwure “A Combination Approach to Face Recognition “, Bishop’s University Sherbrooke, Quebec, Canada November 2015

[100]. Peter N. Belhumeur*, joão P. Hespanha** David J. Kriegman** “Eigenfaces vs. fisherfaces: using class specific linear projection”, Dept. electrical engineering, Yale university, new haven CT 06520-8267,1996.

[101]. Ryan Wilkins,” Neurocognitive Inspired Hierarchical Face Recognition System” University of North Carolina Wilmington,2007.

Appendixes

Appendix A: face detection and recognition snapshots

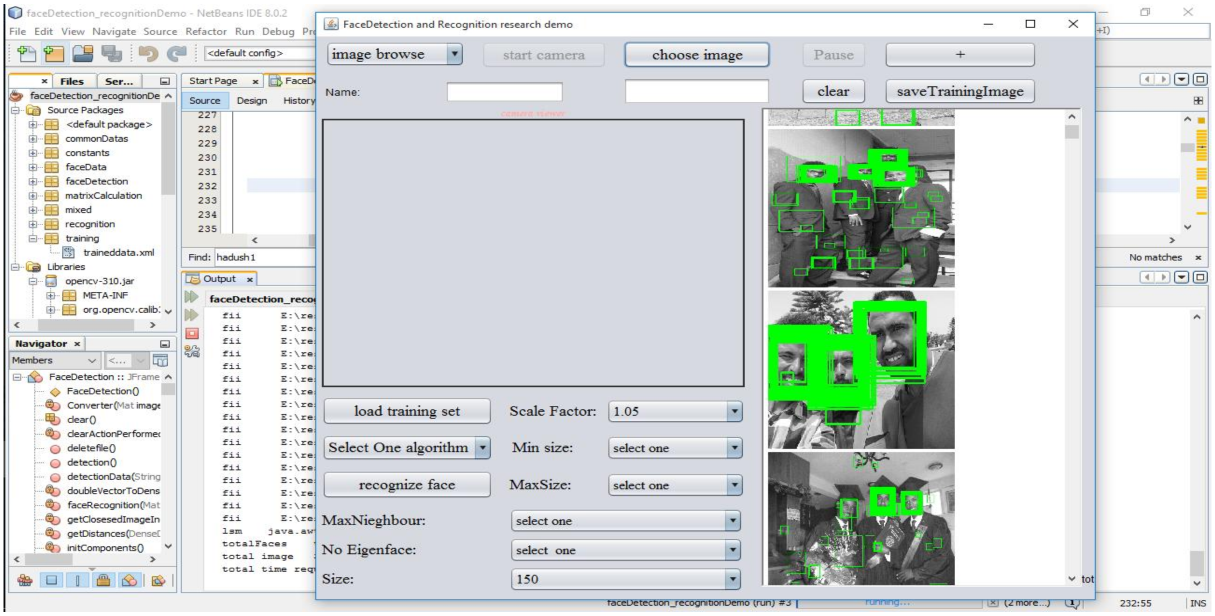


Figure 5.16 face detection snapshot

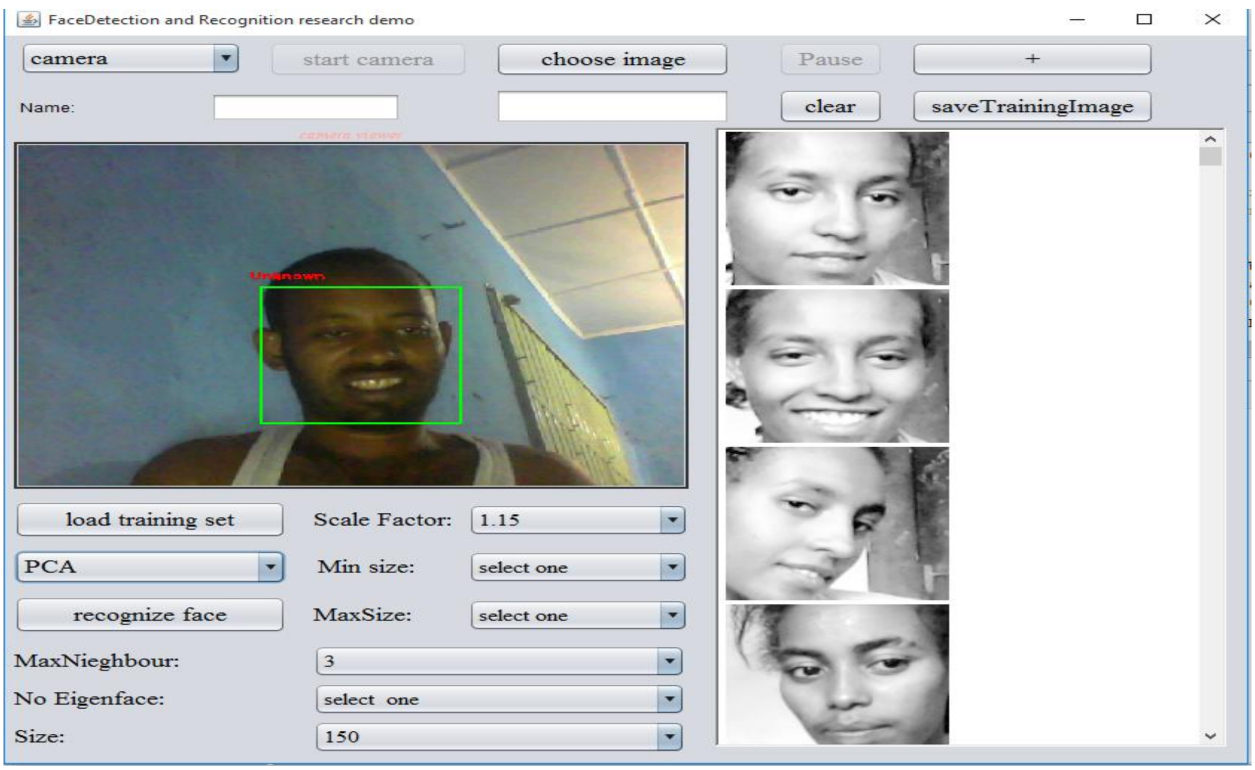


Figure 0.17 real time face recognition snapshot

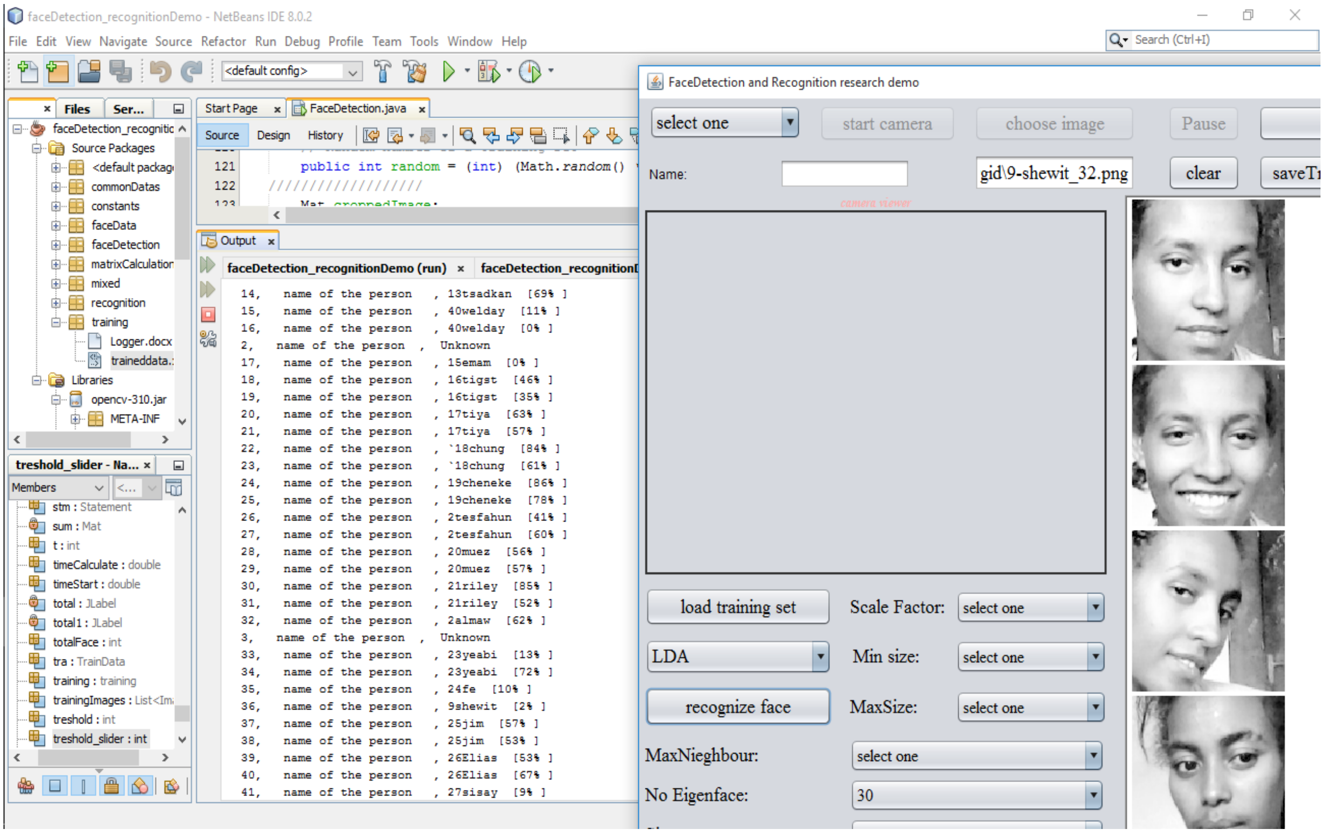


Figure 5.18 face recognition result with confidence

Appendix B:Real time face detection source code

Real time face detection source code

```
 Public class FaceDetection extends javax.swing.JFrame implements Cloneable {
public void run() {
        synchronized (this) {
           while (runnable) {
              if (webSource.grab()) {
                 try {
                    webSource.retrieve(frame);
                    Graphics g = jPanel1.getGraphics();
                    faceArray = faceDetections.toArray();
                    //Imgproc.cvtColor(frame, frame, Imgproc.COLOR_BGR2GRAY);
                    Size minSize = new Size(minSizeda, minSizeda);
                    Size maxSize = new Size(maxSizeda, maxSizeda);
                    faceDetector.detectMultiScale(frame,        faceDetections,        scalefactor,
minNieghbour1,CASCADE_SCALE_IMAGE, minSize, maxSize);
                    for (int i = 0; i < faceArray.length; i++) {
                       Imgproc.rectangle(frame,  new  Point(faceArray[i].x,  faceArray[i].y),  new
Point(faceArray[i].x + faceArray[i].width, faceArray[i].y + faceArray[i].height),
                             new Scalar(0, 255, 0), 2);
//                        Imgproc.rectangle(frame, faceArray[i].tl(), faceArray[i].br(), new Scalar(0,
255, 0), 3);
                       Mat faceROI = frame.submat(faceArray[i]);
                       Imgproc.resize(faceROI, faceROI, new Size(ImageSize, ImageSize));
                       Imgproc.cvtColor(faceROI, faceROI, Imgproc.COLOR_BGR2GRAY);
                       Imgproc.equalizeHist(faceROI, faceROI);
                       Core.normalize(faceROI, faceROI);
                       System.out.println(" the size of an image is " + faceROI.size());
//                      // Use the mask, to remove outside pixels.
                       int desiredFaceWidth = faceROI.width();
                       Mat filtered = new Mat(faceROI.size(), CvType.CV_8U);
                       bilateralFilter(faceROI, filtered, 0, 20.0, 2.0);
                       double FACE_ELLIPSE_CY = 0.56;
                       //Use the "Bilateral Filter" to reduce pixel noise by smoothing the image, but
keeping the sharp edges in the face.
                       // Filter out the corners of the face, since we mainly just care about the
middle parts.
                       // Draw a filled ellipse in the middle of the face-sized image.
                       Mat mask = new Mat(faceROI.size(), CvType.CV_8U, scalar1); // Start with
an empty mask.
                       Point    faceCenter    =    new    Point((desiredFaceWidth)    /    2,
Math.round(desiredFaceWidth * FACE_ELLIPSE_CY));
                       Size    size1    =    new    Size(Math.round(desiredFaceWidth    *
FACE_ELLIPSE_CY - 10), Math.round(desiredFaceWidth * FACE_ELLIPSE_CY - 14));
                       ellipse(mask, faceCenter, size1, 0, 0, 360, scalar, CV_FILLED);
                       Mat    dstImg    =    new    Mat(faceROI.size(),    CvType.CV_8U,    new
```

```
Scalar(ImageSize));
                    //Apply the elliptical mask on the face.
                    filtered.copyTo(dstImg, mask);
//                    // Copies non-masked pixels from filtered to dstImg.
                    imwrite("E:/research databases/trainingFaces/mask.png", faceROI);
                    // Imgproc.resize(faceROI, faceROI, size);
                    if (dstImg != null && (algorithmActivation == 1 || algorithmActivation ==
2)) {
                        double[] returnedResults = faceRecognition(faceROI);
                        int prediction = (int) returnedResults[0];
                        double confidence = returnedResults[1];
                        int label = prediction;
                        String name;
                        double percentage1 = (100 * (treshold - confidence) / treshold);
                        System.out.println(" images    " + names.get(label) + "  [" + percentage1 +
"% ]");
                        if (names.containsKey(label)) {
                            name = names.get(label);
                            Imgcodecs.imencode(".jpg", imageList, mem);
                            byte[] ArrayByte = mem.toArray();
                            InputStream in = new ByteArrayInputStream(ArrayByte);
                            BufferedImage buferImage = ImageIO.read(in);
                            Image myImage = buferImage.getScaledInstance(150, 150,
Image.SCALE_FAST);
                            ImageIcon imIcon = new ImageIcon(myImage);
                            model.add(countImage, imIcon);
                            lsm = new JList(model);
                            System.out.println("lsm    " + lsm.size());
                            scrollPane1.add(lsm);

                        } else {
                            name = "Unknown";
                            System.out.println(" unknown");
                        }
                        // Create the text we will annotate the box with:
                        String box_text = name;
                        System.out.println("Name   =     " + name);
                        // Calculate the position for annotated text (make sure we don't
                        double pos_x = Math.max(faceArray[i].tl().x - 10, 0);
                        double pos_y = Math.max(faceArray[i].tl().y - 10, 0);
                        Imgproc.putText(frame, box_text, new Point(pos_x, pos_y),
                                Core.FONT_HERSHEY_PLAIN, 1.0, new Scalar(0, 0, 255, 2.0), 2);
                    } else if (algorithmActivation == 0) {
                        System.out.println("\"face NO = \" + faceArray.length" +
faceArray.length);
                        //Imgproc.putText(frame, "face NO = " + faceArray.length, new
```

```
Point(faceArray[i].width - 120, faceArray[i].height - 100), 0, 1, new Scalar(0, 0, 255), 2);
                        }
                        eyeArray = eyeDetections.toArray();
                        eyeDetector.detectMultiScale(faceROI, eyeDetections);
                        for (int j = 0; j < eyeArray.length; j++) {
                            eyeData = new Point(faceArray[i].x + eyeArray[j].x + eyeArray[j].width *
0.5,
                                    faceArray[i].y + eyeArray[j].y + eyeArray[j].height * 0.5);
                            int widthHieght = (int) Math.round((eyeArray[j].width +
eyeArray[j].height) * 0.25);
                            Imgproc.circle(frame, eyeData, widthHieght, new Scalar(255, 0, 255), 4,
8, 0);

                        }
                    }
                    Imgcodecs.imencode(".png", frame, mem);
                    Image im = ImageIO.read(new ByteArrayInputStream(mem.toArray()));
                    BufferedImage buff = (BufferedImage) im;
                    if (g.drawImage(buff, 0, 0, getWidth() - 400, getHeight() - 400, -5, -25,
buff.getWidth(), buff.getHeight(), null)) {
                        if (runnable == false) {
                            this.wait();
                        }

                    }
                } catch (Exception ex) {
                    System.out.println("Error");
                }
            }
        }}}
```