FACIAL RECOGNITION AS PASSWORD IN NIGERIAN SECURITY PRINTING AND MINTING (MINT)

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Abstract

While face recognition is hardly a task for humans, it is a complex task for computers. A lot of research has been done in search of an algorithm to teach a computer facial recognition. The current growth in face recognition technology and the lack of a sound security system at Nigerian security, printing and minting (MINT) inspired me to create a security system using face recognition for the security department in Nigerian security, printing and minting (MINT). A lot of the defense applications, security applications and commercial applications require real time face recognition systems. This paper discusses on the existing technique that is applied to face recognition, particularly the Turk and Pentland 'Eigenface' technique. The explanation in this paper covers the Eigenfaces technique used in face recognition.

Keywords: Face Recognition, Nigerian security, printing and minting (MINT), Biometric, Password, Eigenface.

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Chapter 1. INTRODUCTION

The foundation of this project is biometrics. Biometrics is the automated process where a person's unique physical traits are detected and recorded by an electronic system to confirm identity. Facial recognition is one biometric method that has taken the world by storm. This project is basically talking about facial recognition. A research was done to determine the different applicable techniques, the various databases available for facial recognition. The main aim of this project is to create facial recognition security software for The Nigerian Security Printing and Minting Company Limited Plc. Commonly known as MINT. There are two branches of Mint in Nigeria, one in Abuja and the other in Lagos. This project is concerned with the Abuja branch, which is the heart of the company because it is situated in the Capital of Nigeria.

This project falls under the Principal Component Analysis (PCA) category. PCA is a statistical technique that has produced applications in face recognition; it is also a popular technique for pattern finding in data of high dimension. PCA is based on information theory concepts that compute a model that best describes a face. This project is based on Eigenface approach, which is a principal component analysis method, where a small set of images are used to provide the difference between face images. Its secret weapon is that it finds the eigenvectors (eigenfaces) of the covariance matrix of the images stored in memory, the recognition aspect is performed by projecting a new image into the subspace stretch over by the eigenface and then specifying the face as known by comparing its position in face space with the positions of known individuals. Eigenface approach was chosen for this project mainly because of its speed, simplicity and the level of ease to which it is learnt.

The Nigerian security printing and minting company also known, as MINT is the company in charge of printing, developing and storing highly secured and certified documents. Usually these documents have special numbers. The company has two main product lines, which are production of banknotes, coins and security documents. The MINT presently produces more than 40 million notes per week. Security documents are the second product line of the MINT. This is where the production of bank drafts, cheques, stamps, aerogramme, diplomatic documents and treasury bills fall under. There is also another department under security documents in charge of the production of ballot papers and election materials that require security printing, revenue collection, regulation instruments like customs and immigration documents, toll collection and entertainment tickets, tax receipts, examination papers, educational certificates, gift and fuel vouchers, purchase orders and lottery tickets. [1] The current security system in MINT is not reliable, because it is done manually by signing in and signing out. Based on the weakness and the high corruption rate in the organization there have been many reports of money laundering. Recently about four months ago in December 2012 there was a huge scandal about a whopping sum of 2.1 billion Naira that mysteriously went missing.

1.1 Problem Statement

MINT plays an essential role in Nigeria's economy, but the present security system is not assisting in making the organization more secure, hence a robust security mechanism is required to increase the security level. This project is to replace the current security system with a more authentic technique by using facial recognition as the password for access to highly secured parts of the organization.

1.2 Scope

The aim of this project is to develop a face recognition system as a security password for The Nigerian Security Printing and Minting Company Limited Plc. (MINT). Eigenface algorithm was used for the implementation of this project. By creating this software this will provide The Nigerian Security Printing and Minting Company Limited Plc. (MINT) the means to increase their security level with a cost effect and easy to use system.

1.3 Objectives

The ultimate objective of this project is to increase the security level and reduce the level of corruption at MINT; and by creating a robust security system the corruption level will reduce and directly or indirectly this will affect the corruption rate in Nigeria. Another objective is to create a security system that is made of facial recognition to replace the existing security system at MINT.

1.4 Methodology

Research methodology is a set of structured processes used to develop a system. Agile methodology was used to create this system, because my project required me to keep making changes to the phases at different points as I moved along in the project and understood how the system should be implemented. Agile model is a combination of iterative and incremental process models, which focus on process adaptability and customer satisfaction by rapid delivery of working software product [59].

1.5 Project Procedure

Software Development Life Cycle (SDLC) was used to create this system. Software Development Life Cycle is a process for planning, creating, testing, and deploying software. For this project there were a few changes made to the typical SDLC, the procedure used to create this software consists of six phases, each phase has its own process and deliverables that serve as valued information to the next phase. The phases are: Background, Requirements, Design, Implementation, Testing and Deployment. The background phase includes a review of literature on MINT, eigenface, and the available databases for facial recognition. The deliverables of this phase are the information gotten which was useful for the next phase, which is the requirement phase. The requirement phase consists of collection of data through interviews and the examination of the data to emerge with functional, non-functional and user requirement, these requirements were used to deduce the next phase, which is the design phase. The design phase is where the model of the application is created. The implementation phase is where the application is developed in accordance to the requirements. The testing phase is done to check if the application is working and debug when necessary. Feedback is given and the SDLC is repeated until the application meets the requirement of the clients. Deployment is achieved when the application meets the requirement of the client.

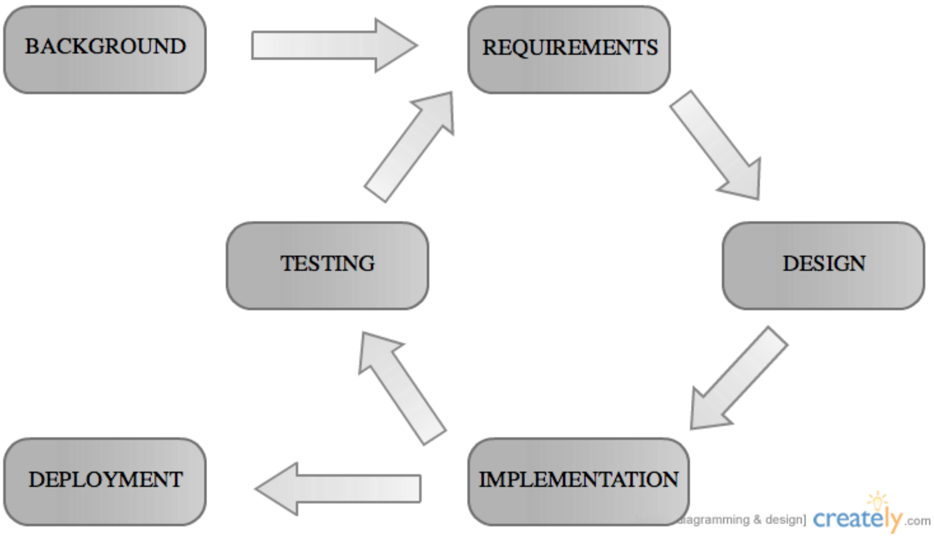


Figure 1: System Development Life Cycle

Chapter 2. BACKGROUND

2.1 Related Work

Over the last decade or more facial recognition has become a force to reckon with in the world if technology. It is the most successful if not the only application of image processing and analysis. It is mainly used in security systems. The amazing thing about facial recognition is that not only computer scientists are interested in it, but also more fields of research. A facial recognition system is a computer application that automatically identifies and recognizes a person by weighing selected facial features from the image against a facial database.

Nigerian security printing and minting company popularly known, as MINT is the company in charge of printing, developing and storing highly secure and certified documents. Usually these documents have special numbers. The company has two main product lines, which are production of banknotes, coins and security documents. The MINT presently produces more than 40 million notes per week. Security documents are the second product line of the MINT. This is where the production of bank drafts, cheques, stamps, aerogramme, diplomatic documents and treasury bills fall under. [1]

Nigerian security printing and minting company is supposed to be the most secure company in Nigeria, unfortunately it is not. There have been many reports of money laundering. The main problem comes from the security aspect of the company. This project is going to solve this security problem. Facial recognition is an amazing invention and what way to utilize this invention? By making facial recognition a password the security level in Nigerian security printing and minting company will increase and if any money laundering problem should arise the project will help solve the problem. MINT is one of the sensitive organizations in Nigeria that is dealing with the currency printing and storage of secret documents. Hence a robust security mechanism is required to protect the legitimate information. This project is to develop a system to replace the existing security procedure with a more authentic technique of using facial recognition as an access to the highly secure zone of the organization.

Facial recognition is a biotech approach that automatically verifies and identifies a living person through the person's physiological characteristics. Generally, a biometric recognition system is based on either physiological characteristics (such as a fingerprint, iris pattern, or face) or behavior patterns (such as handwriting, voice, or key-stroke pattern) to verify a living person. Biometric devices can be made clear through a three- step procedure the first step is executed using a sensor, the second step is executed using an algorithm, and the final step is executed using a matcher. First step: a sensor observes from outside. Both the sensor and observation technique depend on the biometric devices utilized. The output of the observation is a "Biometric Signature" of the person. Second step: the biometric signature is then "normalized" by a computer algorithm so that it has the same format (size, resolution, view, etc.) as the signatures on the system's database. The output of this normalization of the biometric signature is a "Normalized Signature" of the person. Third step: The normalized signature is then compared by a matcher with the set (or sub-set) of normalized signatures on the system's database and supplies a "similarity score" that analyzes the person's normalized signature with each signature in the database set (or sub-set). Processing of the similarity score mostly depends on the biometric system's application?

The application of face recognition technique can be classified into two main parts: law enforcement application and commercial application. Even though face recognition is mainly used in law enforcement applications, this project is based on the commercial application aspect. The commercial applications is vast it ranges from matching and corresponding pictures on credit cards, passports, picture ID to real-time corresponding with still images or video image sequences for access control [42].

The evolution of facial recognition is extremely impressive. This advancement has taken facial recognition to the extent that it is being implemented in real-world scenarios [46]. The active development of face recognition is hugely because of a collaboration of factors: active development of algorithms, the availability of large databases of facial images, and a method for evaluating the performance of face recognition algorithms [42]. Facial recognition problem are regarded as: given still or video images of a scene, identify or verify one or more persons in the scene by comparing with faces stored in a database [42]. When dealing with comparing person verification to face recognition, there are various forms. First form, a user or client is ascertained to be harmonious and makes an identity claim. On a computer level this indicated that it is not fundamental to go and verify with the images in database in order to authenticate the user or client's claim. The input image is then correlated to a small unit of stored images of the user or client whose identity is authenticated and not. In the recognition scenario, with every image (or some descriptor of an image) is stored in a large database. The second form, an automatic authentication system must work closely to real time to be approved by users [42], finally, in facial recognition experiments, only pictures of people from the database are installed in the system, while in the case of a strange face or unknown face it is extremely useful for verification and authentication.

2.1.1 NEC NeoFace

NEC NeoFace technology is a system that uses face recognition for access control in various field and applications. NeoFace, divides the input image and the registered image into small segments, and only focuses on highly similar segments of the face. This gives you a more authentic match, even if a mask or glasses hide part of the subject's face, for example [58].

Some features of NeoFace include:

- 1:1 verification
- 1:n identification
- GLVQ based multiple matching face detection
- Recognition based on neural network technology
- Head, face and eye position detection

It is a powerful technology as it can withstand various quality levels; it has overcome many constraints related to face recognition. NEC's Neoface has provided various solutions such as: NeoFace smart ID, NeoFace watch and NeoFace reveal. NeoFace smart ID is the closest to my project.

2.1.1.1 NeoFace Smart ID

NEC developed a mobile face recognition system to assist law enforcement, public safety and security agencies with their various operations, which include the identification of people. NeoFace Smart ID is a mobile application for commercial-off-the-shelf (COTS) smartphones and tablets equipped with multi-biometric capture capability. It is a multimodal biometric because it captures the face, finger and voice. It operates on system agnostic, including iOS, Android, and Windows.

2.1.1.2 NeoFace For Universal Studio Japan

NEC developed a face recognition system for universal studio Japan that does both detection and matching in one go. It calculates the eye position from the photograph and uses NEC's GLVQ algorithm to define face area. It is used as an access control system for the visitors with annual passes; instead of showing the tickets every time they visit the park they can simply scan their faces and get access.

2.2 General Research Methodology

2.2.1 Face Recognition

Face recognition is a sophisticated biometric. It is a pattern recognition method done specifically on faces. It compares input images with stored images of identified individuals and classifies the input image as "known" if the image matches any stored image and classifies the input image as "unknown" if the image does not match any stored image. It also learns to recognize unknown faces too by storing the image into the database. In this project, the main focus is on image-based face recognition. Where a picture is taken from a digital camera, and we would like to know if the person in the picture is a "known", in other words if the person is identified as an employee at MINT with access to the system and an "unknown" is an imposter to the system. Face recognition is divided into three steps: Face Detection, Feature Extraction, and Face Recognition respectively. These three steps are the general steps of face recognition.

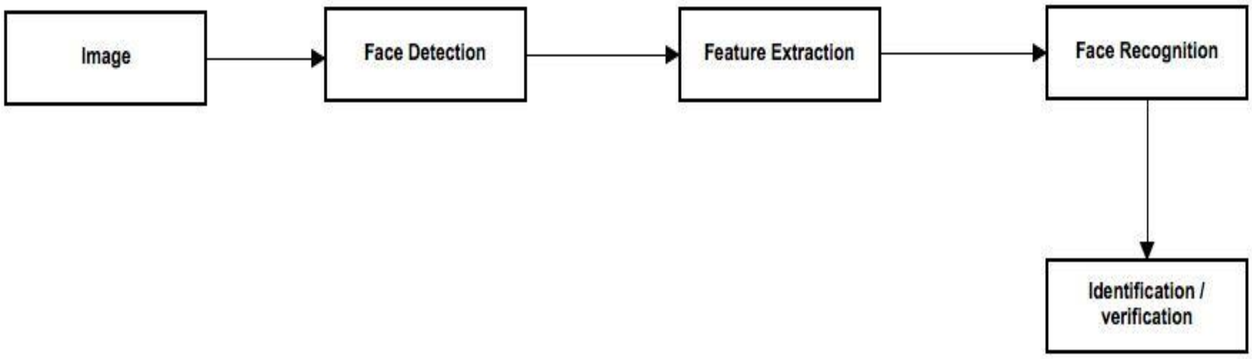


Figure 2: General Steps of facial recognition

2.2.1.1 Face Detection

This step serves as the pre-processing step of facial recognition; it has two main functions (1) checks if there is a human face in the given image, and (2) finds the location of the face. The output of this step is that there should be a patch on the face in the given image. For additional accuracy face alignments are performed to confirm the scales and orientations of the patch.

2.2.1.2 Feature Extraction

This step comes after the face detection step; the face patch is obtained from the image. In some researches and literature reviews, feature extraction is done either in face detection or face recognition.

2.2.1.3 Face Recognition

This is the final step after formulizing the representation of each face; where the face is recognized and identified. To achieve the recognition and identification a face database is needed, because when an input image is given and face detection and face extraction have been performed, we can then compare the obtained features to each face class saved in the face database. There are generally two applications of face recognition, which are identification and verification. Identification is when an input image is given; we want the system to output the identification of the person in the image; while verification is when a face image is given and a guess of the identification are given as the input, and we want the system to validate the guess .In this project only the identification aspect will be used.

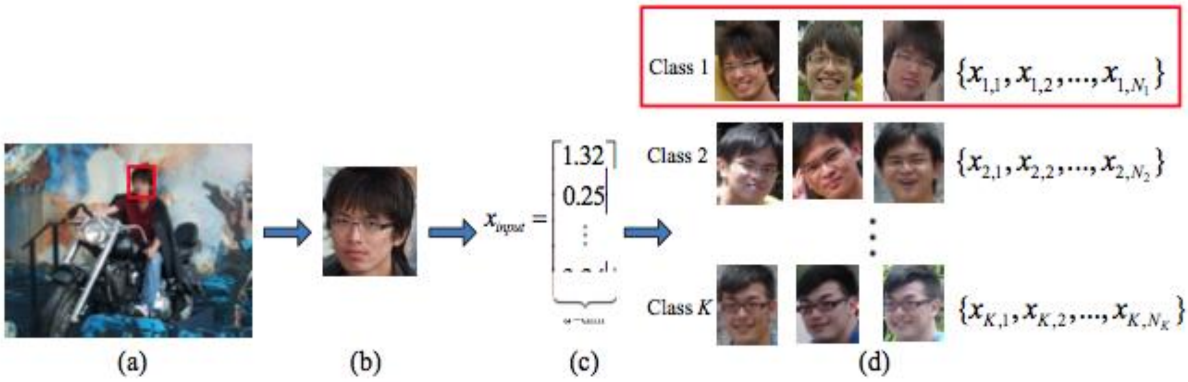


Figure 3: Implementation of the three recognition steps

This is an example of the implementation of the three facial recognition steps on an input image. (a) The input image and the aftermath of face detection (the red patch) (b) Extracted face patch (c) The feature vector after feature recognition (d) Comparing the feature vector with the saved vectors in the face database using facial recognition classification techniques and determining the most appropriate class (class 1)

2.2.1.3.1 In Depth Description Of A Facial Recognition System

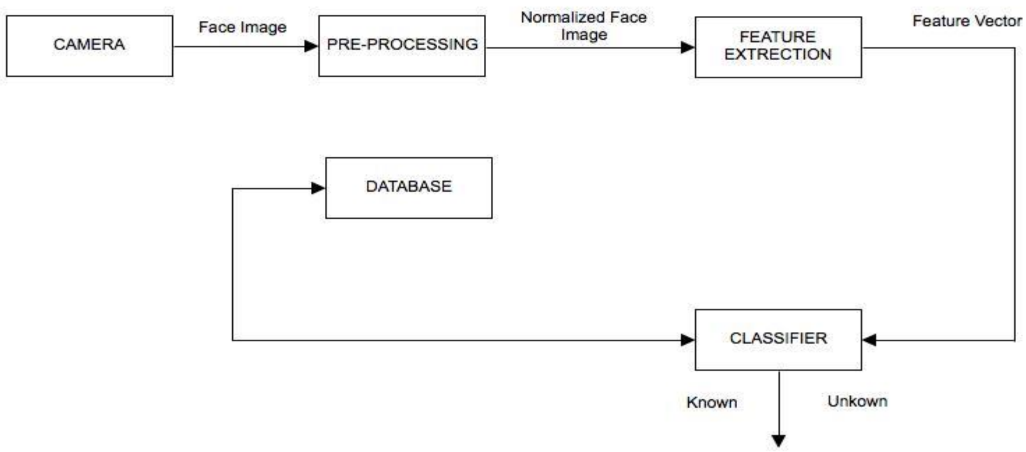


Figure 4: in-depth block diagram of facial recognition

There are five main functional blocks, camera, pre-processing, feature extraction, classifier and database.

1. Camera: The starting point of the facial recognition system, it is the entry

point of the face recognition.

2. Pre-processing module: this is the stage where face images are normalized, and if wanted images are enhanced to improve the performance of the recognition system.

3. Feature extraction: after performing the pre-processing (if required), the input image for the feature extraction stage is the normalized image. It is presented to the feature extraction module to locate the key (important) features that are needed for classification.

4. Classifier: This is the stage where a face is classified either as "known" or "unknown". In this module a pattern classifier is needed, with the pattern classifier extracted features are compared with the stored ones in an image depository. After the comparison, the face image is classified as "known" or "unknown"

5. Database: this is where feature vectors are stored. After an image has been classified as an "unknown" it can be added to the library (if wanted).

Face recognition is considered to be a complex task due to enormous changes produced on face by illumination [13], facial expression, size, orientation, accessories on face and aging effects. The difficulty level increases when two persons have similar faces.

2.2.1.3.2 Different Approaches Of Face Recognition

There are three different approaches for face recognition. First is holistic method that exploits eigenfaces, fisher faces, etc. these algorithms are considered complex due to the fact that the whole face is used for detection purposes. Second method is features based which depends on edges, lines, and feature templates; it is commonly used because it is considered to be less complex and has an accepted accuracy. The third method is hybrid; this method uses both feature extraction and holistic due to the combination if these two methods the hybrid method produces a more accurate result with high efficiency.

Holistic method: In holistic method, the whole face region is considered as the input data to the face recognition system.

Feature based method: The feature-based method; facial features such as eyes. Nose, mouth etc are detected and then compared with the detected facial features in the database.

Hybrid method: is the mixture or combination of both the holistic method and the feature based method.

2.3 Selected Research Algorithm

The chosen algorithm for this project is Eigenface, it was mainly for two reasons (1) it assumes that most faces are under similar conditions (2) it appeared to be the most suitable method to use in face recognition because it is simple, fast and most importantly it is easy to learn. The eigenfaces technique falls under the holistic method because it applies the Principal Component Analysis (PCA) method.

2.3.1 EIGENFACE BASED RECOGNITION

The first record of Eigenface dates back to 1990 when Kirby and Sirovich wrote about the 'Eigenface' approach (reference na Kirby from paper 1), after them many papers have been written, referring to their primitive idea. Turk and Pentland presented the revolutionary "Face Recognition Using Eigenfaces" in the year 1991. Works cited by Turk and Pentland are from three major categories: feature based face recognition, connectionist based face recognition and geometric face recognition. Turk and Pentland came up with an algorithm that addresses the face recognition problem as a two dimensional problem, which considers most faces are under similar conditions.

The underlying idea of their algorithm is that input images are compared to the images of known faces and checks whether the input face matches one of the known faces or if it an unknown face or if it is not a face. For these comparisons to take place a face database is needed. According to Turk and Pentland's algorithm instead of storing the entire image information of the whole set of known faces; just store the Eigenfaces (faces formed by eigenvectors). The entire Eigenfaces put together produce a "face space"; the face space is where new faces are projected. The eigenface technique is simple, efficient, and generally produces good results when the circumstances are controlled. There are five steps involved in the system developed by Turk and Pentland. The steps are:

1. Initialization: this is the stage where the training set of face images is gotten and the "eigenfaces" are calculated, which describes the "face space".

2. Projection: when a new image is met, calculate the set of weights based on the input image and the M (eigenface) by projecting the input image onto each eigenface.

3. Detection: decide if the image is a face (known, unknown or a face at all) by verifying if the image is adequately close to the "face space".

4. Recognition: if the image is a face, then classify the weight pattern as a "known" or "unknown" person.

5. Learning: if an identical unknown face is detected several times, calculate its characteristic weight pattern and integrate it into the known faces.

2.3.1.1 EIGENFACES ALGORITHM PROCEDURE

1. The first stage is to acquire a set of images (training set) into a database.
2. The second stage is to create the eigenfaces. Extracting characteristic features from the faces creates Eigenfaces. The input images are normalized to line up the eyes and mouths. They are then resized so that they have the same size. Eigenfaces can now be extracted from the image data by using a mathematical tool called Principal Component Analysis (PCA).
3. Since the eigenfaces have been created, each image is then represented as a vector of weights.
4. The system is now prepared to accept incoming images.
5. The weight of the input image is found and then compared to the weights of the known images in the system. If the input image's weight is beyond a given threshold it is classified as unknown. To classify the input image as known; find the image in the database whose weights are closest to the

weights of the input image, then return the image in the database as a hit to the user of the system.

Figure 5: Eigenface Flowchart

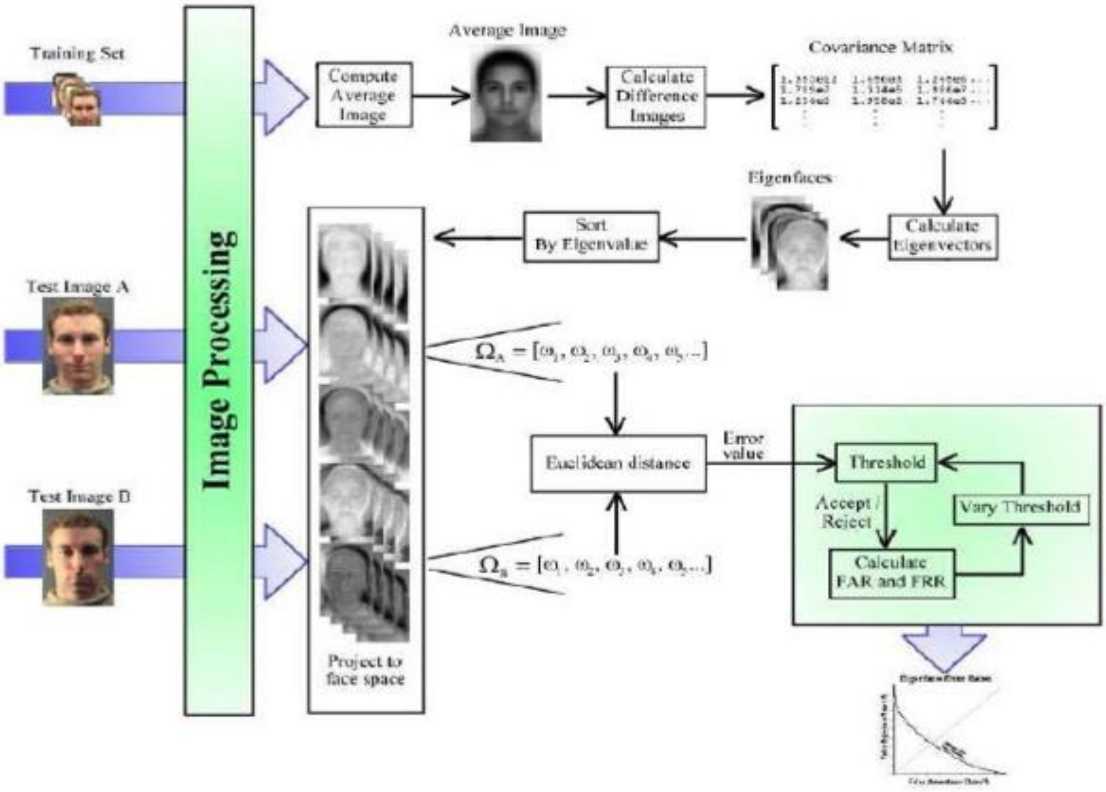


Figure 6: Eigenface Approach

Face Recognition Process using Eigenface approach from the above diagram.

1. The training set of images is given as input to find eigenspace.
2. Using these images, the average face image is calculated.
3. The difference of these images is represented depicted by covariance matrix.
4. This is used to calculate Eigenvectors and Eigenvalues. These are the Eigenfaces that represent various face features.
5. Sort the eigenvalues, and consider higher of them since they represent maximum variations. This becomes eigenspace spanned by the eigenfaces, which has lower dimension than original images?
6. Now given two test images are projected onto this eigenspace to give the weight vector also known as Face key for that image.
7. The Euclidean distance between these two face key vectors is calculated. If this is below some threshold value, then two images are said to be matching that means they belong to same person.
8. Depending on this result, False Acceptation Rate (FAR) and False Rejec-

tion Rate (FRR) are found. These are used to change value of Threshold. In this way Face Recognition is carried out using Eigenface Approach.

Advantages of facial recognition system

- No physical contact required
- Easy access to Sensors (cameras)
- Results verification are easy

Disadvantages of facial recognition system

- Obstruction is easy. Example obstruction caused by hair or scarves
- Face changes overtime
- Sensitive to changes in lighting, expression, and pose
- Twin can have access of each others personal information

2.4 Available Database

To build a database for each person, several images are taken in different angles, lighting etc, where their features are withdrawn and stored in the database. Using a standard test data set gives researchers the freedom to directly compare the results and using standard test data set is highly encouraged. Even though with the unlimited options of database currently in use, choosing a good database should depend on the given task. Another possible approach is by choosing the data set particularly concerned with the property that is going to be tested. There are various face databases but only 4 databases are discussed; these 4 databases are based on a review done on them by Ralph Gross, they are publicly accessible for facial recognition. The following are the databases: AR Database, BANCA Database, CAS-PEAL Database, and FERET. At the start of each database description there is a table summarizing the main features of the database, features like address, the number of subjects, recording conditions, image resolution, and total number of images. All databases discussed here accommodate full-face imagery. Databases are important because the type of database that is being used affects the performance of an algorithm.

2.4.1 AR Database [17]

No. Of subjects	Conditions		Image Resolution	No. Of Images
166	Facial expression	4	768 x 576	3288
	Illumination	4		
	Occlusion	2		
	Time	2		
http://rvl1.ecn.purdue.edu/aleix/aleix_face_DB.html				

Table 1: AR Database

AR Database has 116 images of individuals (63 images are for men and the remaining 53 images are for women). The imaging and recording conditions (camera parameters, illumination setting, and camera distance) were crucially examined to make sure that the settings imply equally for all subjects. The resulting RGB color images are 768 × 576 pixels in size.

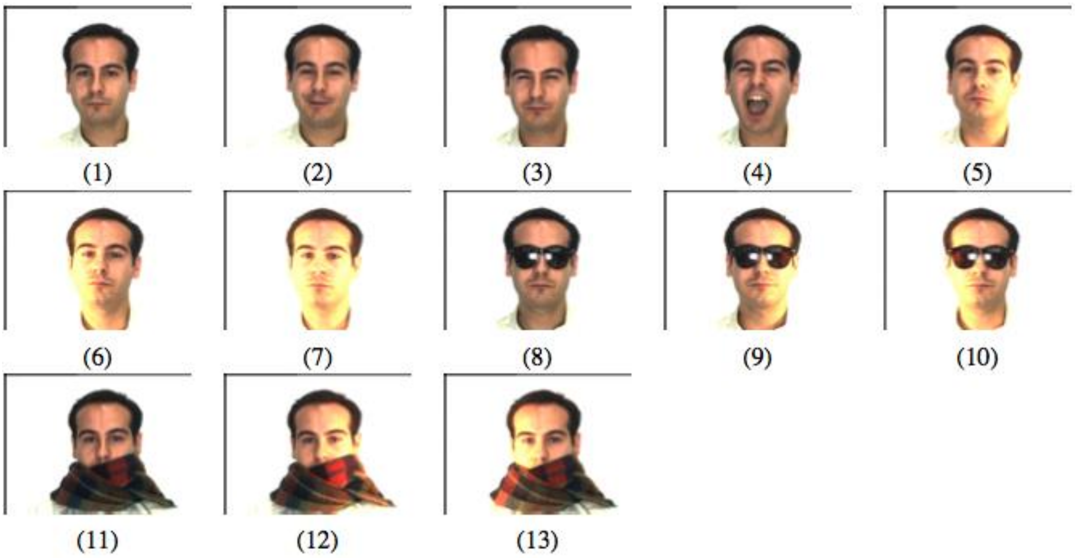


Figure 7: AR Database Image Conditions

These are the conditions: (1) neutral, (2) smile, (3) anger, (4) scream, (5) left light on, (6) right light on, (7) both lights on, (8) sun glasses, (9) sun glasses/left light (10) sun glasses/right light, (11) scarf, (12) scarf/left light, (13) scarf/right light.

2.4.2 BANCA Database [17]

No. Of Subjects	Conditions		Image Resolution
208	Image quality Time	3 12	720 x 576
http://www.ee.surrey.ac.uk/Research/VSSP/banca/			

Table 2: BANCA Database

The reason for developing the database was to test multimodal identity verification with various obtaining devices such as high and low quality cameras and microphones and under several use cases or scenarios like controlled, degraded, and adverse. Collection of data was done for 52 subjects (half were men and half were women) in four languages namely English, French, Italian, and Spanish. Each subject was recorded during 12 different sessions over a period of 3 months [16]. The subjects were recording for an identified or known client access and an unidentified/unknown or imposter attack were done during each session. Random 12-digit number, name, address, and date of birth (client or imposter data) were spoken by the subject for each recording. Recordings took an average of 20 seconds [16].

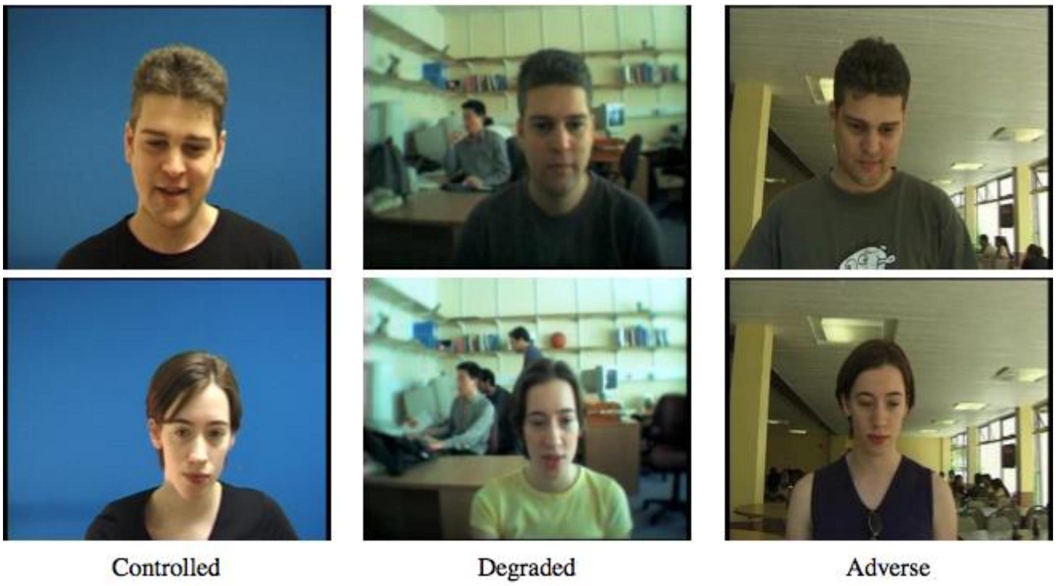


Figure 8: BANCA Database

A high quality digital camera was used to record the images for the controlled and adverse conditions. The images of the degraded condition were taken with a low quality web cam.

2.4.3 CAS-PEAL Database [17]

No.Of Subjects	Conditions		Image Resolutution	No. Of Images
1040	Pose	21		
377	Facial expressions	6		
438	Accessory	6		
233	Illumination	9 – 15	360 x 480	30,900
297	Background	2 – 4		
296	Distance	1 – 2		
66	Time	2		
http://www.jdl.ac.cn/peal/index.html				

Table 3: CAS-PEAL Database

The CAS-PEAL (pose, expression, accessory, lighting). It has 66 to 1040 (with 595 men and 445 women) subjects images in seven categories: pose, expression, accessory, lighting, background, distance, and time [51]. When dealing with pose subset, nine cameras were spread in a semicircle around the subject. Images were recorded in order in 2 seconds. For each recording subjects were requested to look up and down by roughly 30◦.

Figure 9: Pose Variation In The CAS-PEAL Database.

Different cameras recorded the pictures. The cameras are about 22.5 ◦, apart. Subjects looked up, straight ahead, and down.

Recording faces under different but close to real life lighting conditions, constant ambient illumination together with 15 manually operated fluorescent lamps were used. The recording took around two minutes.

Figure 10: Illumination Variation In The CAS-PEAL Database

In the expression aspect of the database, subjects had, to frown, look surprised, close their eyes, and open the mouth. All recordings were taken using nine cameras. A smaller group of subjects were recorded wearing three types of glasses and three types of hats. Finally a small group of subjects returned 6 months later for more recordings. To assist the progress of the database distribution, the release images are saved as cropped gray-scale images of size 360 × 480.

Figure 11: Images Are Gray-Scale And 360 × 480 In Size.

2.4.4 FERET [17]

No. Of Subjects	Conditions		Image resolution	No. Of Images
1199	Face expressions	2	256 x 384	14,051
	Illumination	2		
	Pose	9 – 20		
	Time	2		
http://www.nist.gov/humanid/feret/				

Table 4: FERET

The FERET database documentation mentions 24 facial image categories (reference). Images were recorded with a 35 mm camera. The resulting images are 256

× 384 pixels in size. The subjects display various facial expressions for the fb image. The changes in facial expression are mainly unnoticeable. The images in the fc were recorded under different circumstances. Some of the subjects returned later to record again. For the images in the duplicate I set. A subset of these images forms the duplicate II set.

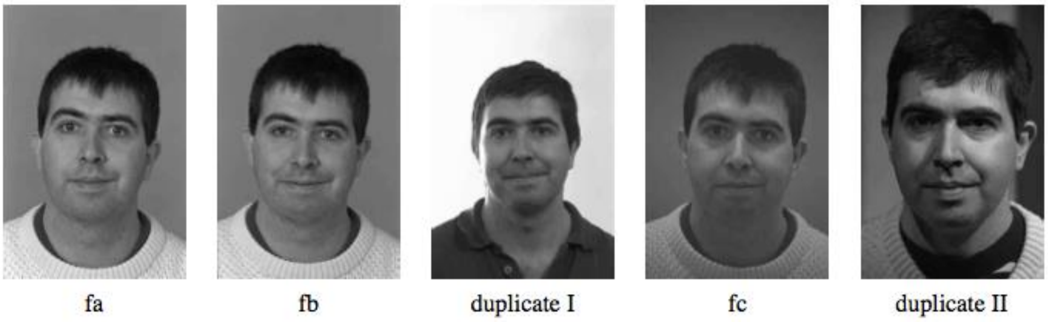


Figure 12: Frontal Image Categories Used In The FERET Evaluations.

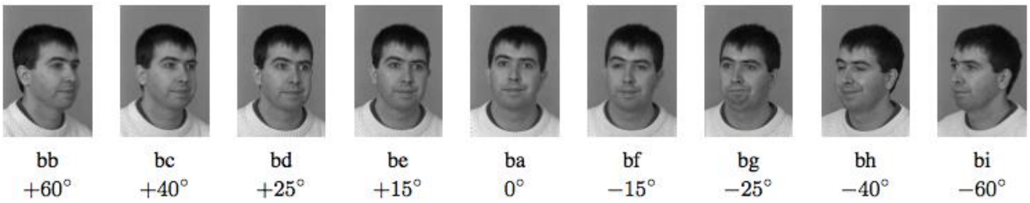


Figure 13: Pose variation in the FERET database.

The poses vary from +60 ◦, (bb) to full frontal (ba) and on to -60 ◦. (bi). Images are available for 200 subjects.

Different sets of pose images were recorded. Images were accumulated at the following head aspects: right and left profile (labeled pr and pl), right and left quarter profile (qr, ql) and right and left half profile (hr, hl). In these categories images were recorded for 508 to 980 subjects [16].

Additional information, including the date of the recording and what the subject was wearing on his face are provided for each image in the data set. 3816 images [16] have the locations of left and right eye and the mouth center.

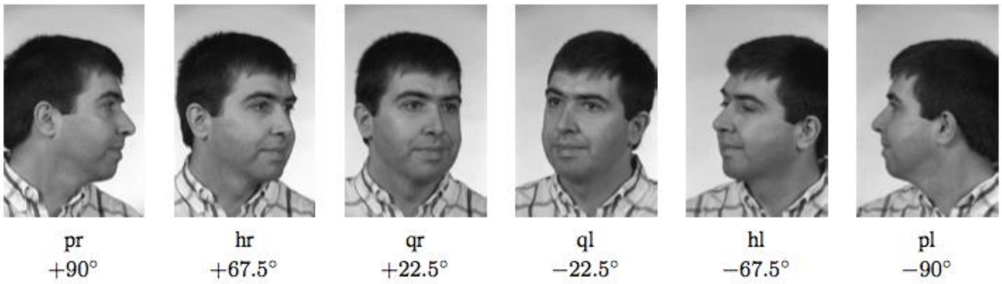


Figure 14: FERET Head Aspects

Images were collected at the following head aspects: right and left profile (labeled pr and pl), right and left quarter profile (qr, ql), and right and left half profile (hr, hl).

Chapter 3. TECHNIQUES

Eigenface algorithm was chosen under holistic methods, it falls under PCA approach, and fisherface algorithm, which falls under LDA approach. Principal Component Analysis (PCA) looks for a small number of features by using the principal components of the face, whereas, Linear Discriminant Analysis (LDA) looks for a small number of features by maximizing the grouping of faces from the same individual and minimizing the grouping of faces from different individuals [8]. One of the main disadvantages of Holistic approach is that the variances (points) taken may not be relevant features of the face like (eyes, nose, eyebrows). Below is a comparison between the two algorithms based on an experiment done by Arati Kothari and Sampatkumari Maruti Bandagar.

3.1 Eigenface Vs. Fisherface Based On An Experiment Done By Arati Kothari And Sampatkumari Maruti Bandagar.

Unfortunately in this experiment they could not test both algorithms in respect to lighting conditions but it is a known fact that Eigenfaces is affected by lighting conditions more than fisherface.

3.1.1 Comparison Based On Size Of Training Data

Both algorithms were tested on 20 images with varying poses in training data. As noticed from the graph below fisherface based algorithm is better than eigenface based algorithm at recognizing images when the number of poses is less. In both cases as the number increases, the difference in the percentage (%) of true recognition is small. The graphical representation of the graph is in figure 13.

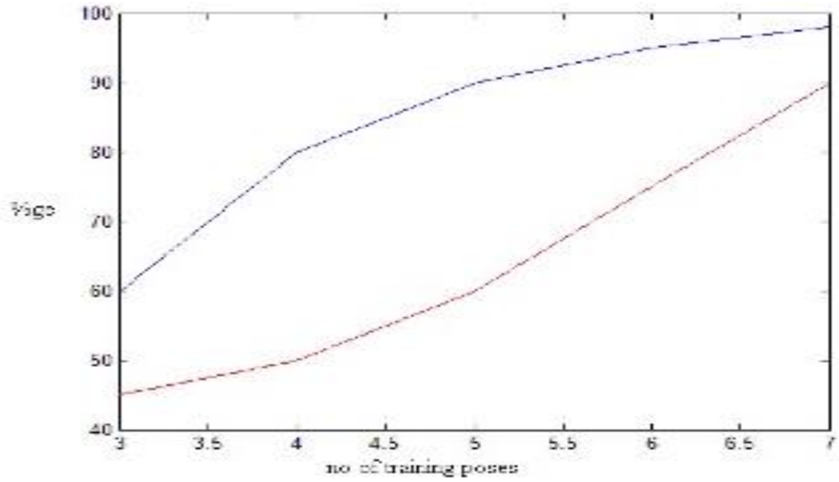


Figure 15: Graph for recognition percentage VS number of training poses.

Blue : fisherface and

Red : eigenface.

3.1.2 Comparisons By Image Pose

Both algorithms were tested in their ideal working conditions for various poses of the same image. For this aspect of the comparison 3 poses were used for fisher-face and 6 poses were used for eigenface and the results yielded were very similar as shown in figure 14. The results from both are acceptable but keep in mind that fisherface was trained with less faces. That is why the closest face images differ.

Figure 15a: Fisherface results

Figure 15b: Eigenface results

3.1.3 Conclusion

A combination of both fisherface algorithm and eigenface algorithm would make a better algorithm and yield better results despite the fact that the available results are good. Both algorithms are good in their own rights. The main source of concern for these two algorithms is the case of robustness vs simplicity. Fisherface is hard to implement in real time due to its computational complexity. Due to this issue of fisherface, it would be a smarter choice of algorithm to use eigenface.

There are several facial recognition techniques such as: Eigenface, 3-D Morphable Model, 3-D Face Recognition, Bayesian Framework, Support Vector Machine (SVM) and Hidden Markov Models (HMM). For this project Eigenface is the technique that will be used.

3.2 Eigenface Algorithm

The base for various studies and investigation are algorithms based on principal component analysis (PCA) or Eigenface, due to its popularity Facial recognition systems are mainly based on PCA it has been applied on various studies such as facial recognition, facial detection and sex classification. Eigenface is also known as Karhunen- Loève expansion, eigenpicture, eigenvector, and principal component analysis. It is considered the first successful example of facial recognition technology. [53]. It is an algorithm that drafts the characteristics of a person's face into a multi-dimensional face shape.

3.2.1 The Eigenface Recognition Procedure According To Ilker Atalay [56].

- Form a face library that consists of the face images of known individuals.
- Choose a training set that includes a number of images (M) for each person with some variation in expression and in the lighting.
- Calculate the M x M matrix L, find its eigenvectors and eigenvalues, and choose the M' eigenvectors with the highest associated eigenvalues.
- Combine the normalized training set of images to produce M' eigenfaces. Store

these eigenfaces for later use.

- For each member in the face library, compute and store a feature vector.
- Choose a threshold ε that defines the maximum allowable distance from any face class. Optionally choose a threshold φ that defines the maximum allowable distance from face space.
- For each new face image to be identified calculate its feature vector and compare it with the stored feature vectors of the face library members. If the comparison satisfies the condition given, then classify this face image as "known", otherwise a miss has occurred and classify it as "unknown" and add this member to the face library with its feature vector.

3.2.2 Eigenfaces Calculation by Turk and Pentland Courtesy of Ilker Atalay [57]

An N x N matrix A is said to have an eigenvector X, and corresponding

$$AX = \lambda X.$$

Evidently, the equation above can hold only if

$$\det\left|A - \lambda I\right| = 0$$

which, if expanded out, is an Nth degree polynomial in λ whose root are the eigenvalues. This proves that there are always N (not necessarily distinct) eigenvalues. Equal eigenvalues coming from multiple roots are called "degenerate".

A matrix is called *symmetric* if it is equal to its transpose,

$$A = A^T \text{ or } a_{ij} = a_{ji}$$

it is termed *orthogonal* if its transpose equals its inverse,

$$A^T A = AA^T = I$$

finally, a real matrix is called *normal* if it commutes with is transpose,

$$AA^T = A^T A.$$

Theorem: Eigenvalues of a real symmetric matrix are all real. Contrariwise, the eigenvalues of a real nonsymmetric matrix may include real values, but may also include pairs of complex conjugate values. The eigenvalues of a normal matrix with nondegenerate eigenvalues are complete and orthogonal, spanning the N-dimensional vector space.

After giving some insight on the terms that are going to be used in the evaluation of the eigenfaces, we can deal with the actual process of finding these eigenfaces.

Let the training set of face images be

$$\Gamma_1, \Gamma_2, \ldots, \Gamma_M$$

then the average of the set is defined by

$$\Psi = \frac{1}{M}\sum_{n=1}^{M}\Gamma_n \, .$$

Each face differs from the average by the vector

$$\Phi_i = \Gamma_i - \Psi \, .$$

This set of very large vectors is then subject to principal component analysis, which seeks a set of M orthonormal vectors, u_n , which best describes the distribution of the data. The kth vector, u_k , is chosen such that

$$\lambda_k = \frac{1}{M}\sum_{n=1}^{M}(u_k^T \Phi_n)^2$$

is a maximum, subject to

$$u_l^T u_k = \delta_{lk} = \begin{Bmatrix} 1, & \text{if } l = k \\ 0, & \text{otherwise} \end{Bmatrix}$$

The vectors u_k and scalars λ_k are the eigenvectors and eigenvalues, respectively of the covariance matrix

$$C = \frac{1}{M}\sum_{n=1}^{M}\Phi_n\Phi_n^T = AA^T .$$

where the matrix $A = [\Phi_1\Phi_2...\Phi_M]$ The covariance matrix C, however is N^2 x N^2 real symmetric matrix, and determining the N^2 eigenvectors and eigenvalues is an intractable task for typical image sizes. We need a computationally feasible method to find these eigenvectors.

If the number of data points in the image space is less than the dimension of the space ($M < N^2$), there will be only M-1, rather than N^2, meaningful eigenvectors. The remaining eigenvectors will have associated eigenvalues of zero. We can solve for the N^2 dimensional eigenvectors in this case by first solving the eigenvectors of an M x M matrix such as solving 16 x 16 matrix rather than a 16,384 x 16,384 matrix and then, taking appropriate linear combinations of the face images $\Phi_{i.}$

Consider the eigenvectors v_i of A^TA such that

$$A^T Av_i = \mu_i v_i$$

Premultiplying both sides by A, we have

$$AA^T Av_i = \mu_i Av_i$$

from which we see that Av_i are the eigenvectors of C □AA^T.

Following these analysis, we construct the M x M matrix L □□$A^T A$, where L_{mn}□□$\Phi^T_m\Phi_n$, and find the M eigenvectors, v_l , of L. These vectors determine linear combinations of the M training set face images to form the eigenfaces u_l .

$$u_l = \sum_{k=1}^{M} v_{lk}\Phi_k \ , \qquad l = 1,...,M$$

With this analysis, the calculations are greatly reduced, from the order of the number of pixels in the images (N^2) to the order of the number of images in the training set (M). In practice, the training set of face images will be relatively small

(M << N^2), and the calculations become quite manageable. The associated eigen-values allow us to rank the eigenvectors according to their usefulness in characterizing the variation among the images.

3.2.3 Advantages And Disadvantages Of Eigenfaces Algorithm

Advantages

- Little processing work needed
- No knowledge of geometry and reflectance of faces is required
- Simplicity
- Speed and insensitivity to small or gradual changes on the face

Disadvantage

- Images view has to be vertical frontal views of human faces
- Lighting must me good

Chapter 4. ANALYSIS AND DESIGN

4.1 Analysis

There are two types of analysis for this system, one is report analysis, which is done in this chapter, and the other is the implementation analysis, which has not been done yet because I will need to test the system in the condition or situation of the room in MINT and then compare it with the current system they have. This chapter focuses on the requirements phase in the System Development Life Cycle. The main objective of this chapter is to have a clear view of the system with detailed descriptions of the

4.1.1 Requirements

4.1.1.1 Non-Functional Requirements

- Lighting: the room should be bright
- Feature changes: there should be minimum feature changes
- Cost-effective

4.1.1.2 Functional Requirements

- Recognize face fast
- Display message
- Add Images

4.1.1.3 User Requirements

- The system should be user friendly
- The system should be fast
- The system should be reliable
- The system should be convenient

- The system should be secured

4.1.1.4 Software Requirement

The operating system used is windows 7 on a 64- bit laptop. The environment used to create the software is MATLAB R2012b (8.0.0.783). The programming language used to develop the software is MATLAB.

4.1.1.5 Use Case Diagram

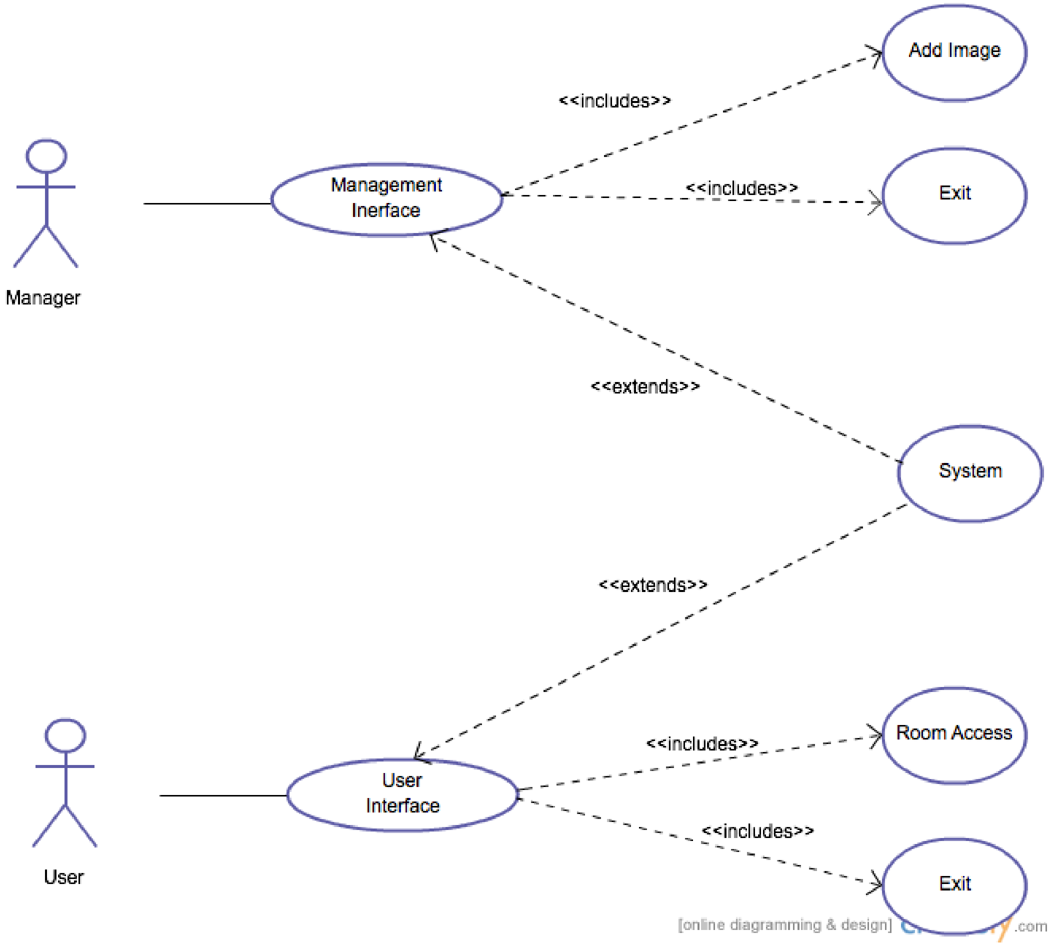


Figure 16: Use Case Diagram

The manager of the application must have authority to access the management interface, which is an extension of the system and should be able to add a new image to the memory and exit. The users would interact with the user interface, which is an extension of the system. The users would be able to request room access and exit.

4.2 The Flowchart

There are two flowcharts. One is for the manager interface and the other one is for the user interface.

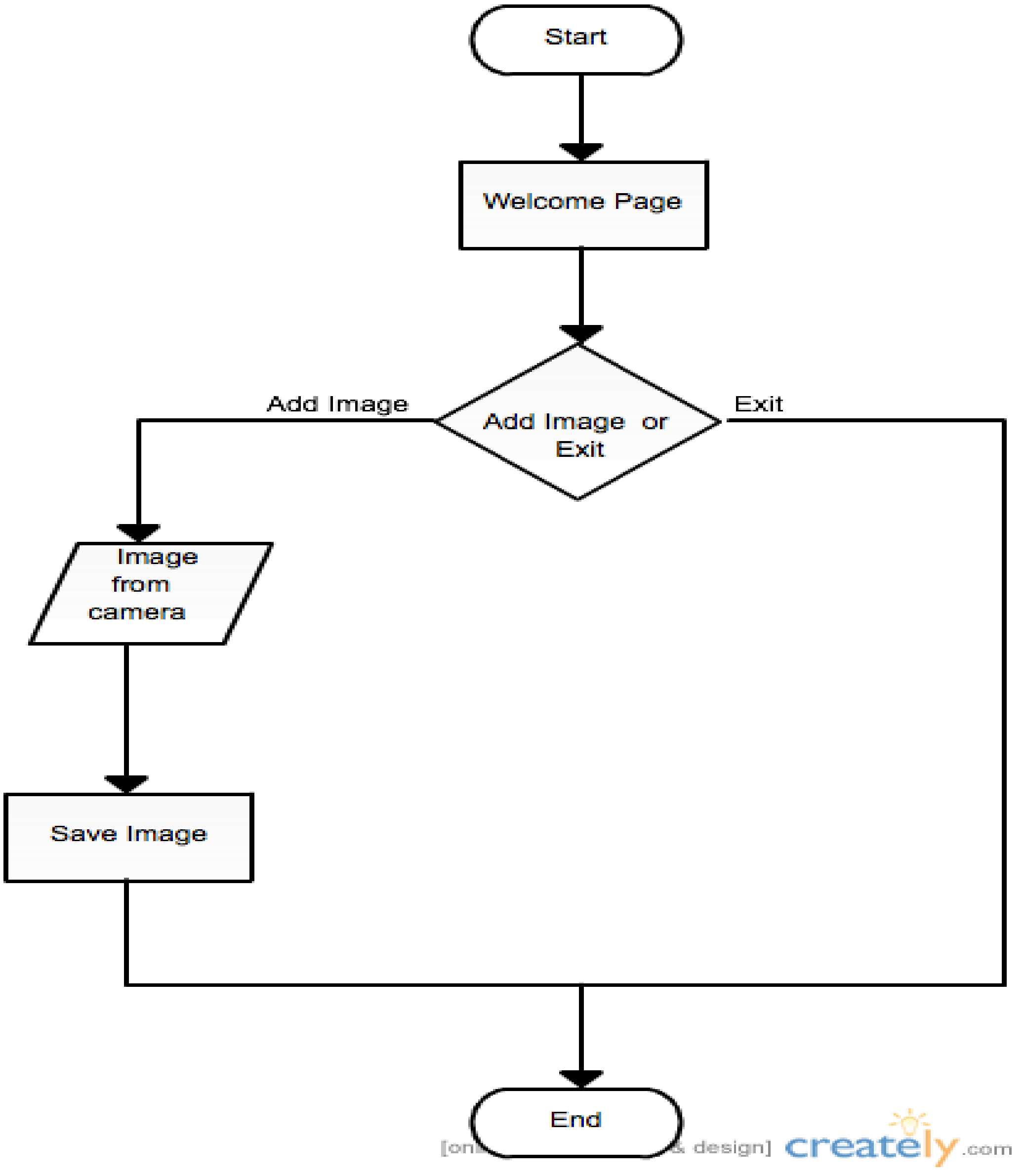


Figure 17 : Project Flowchart For Manager Interface

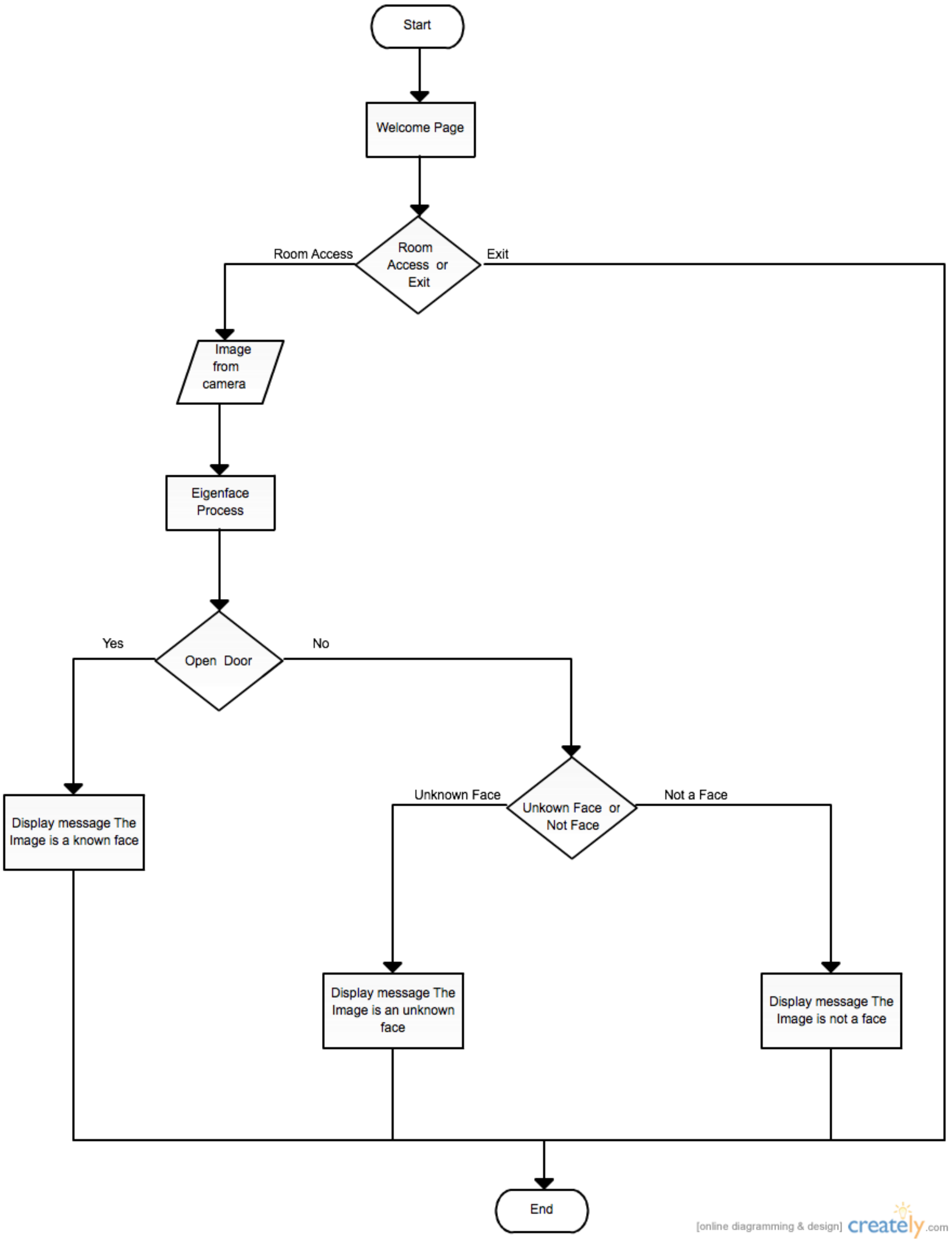


Figure 18: Project flowchart For User Interface.

4.3 Prototype

There are two Prototypes one is for an Employee at MINT and the other is for an Imposter.

4.3.1 Scenarios

4.3.1.1 Employee

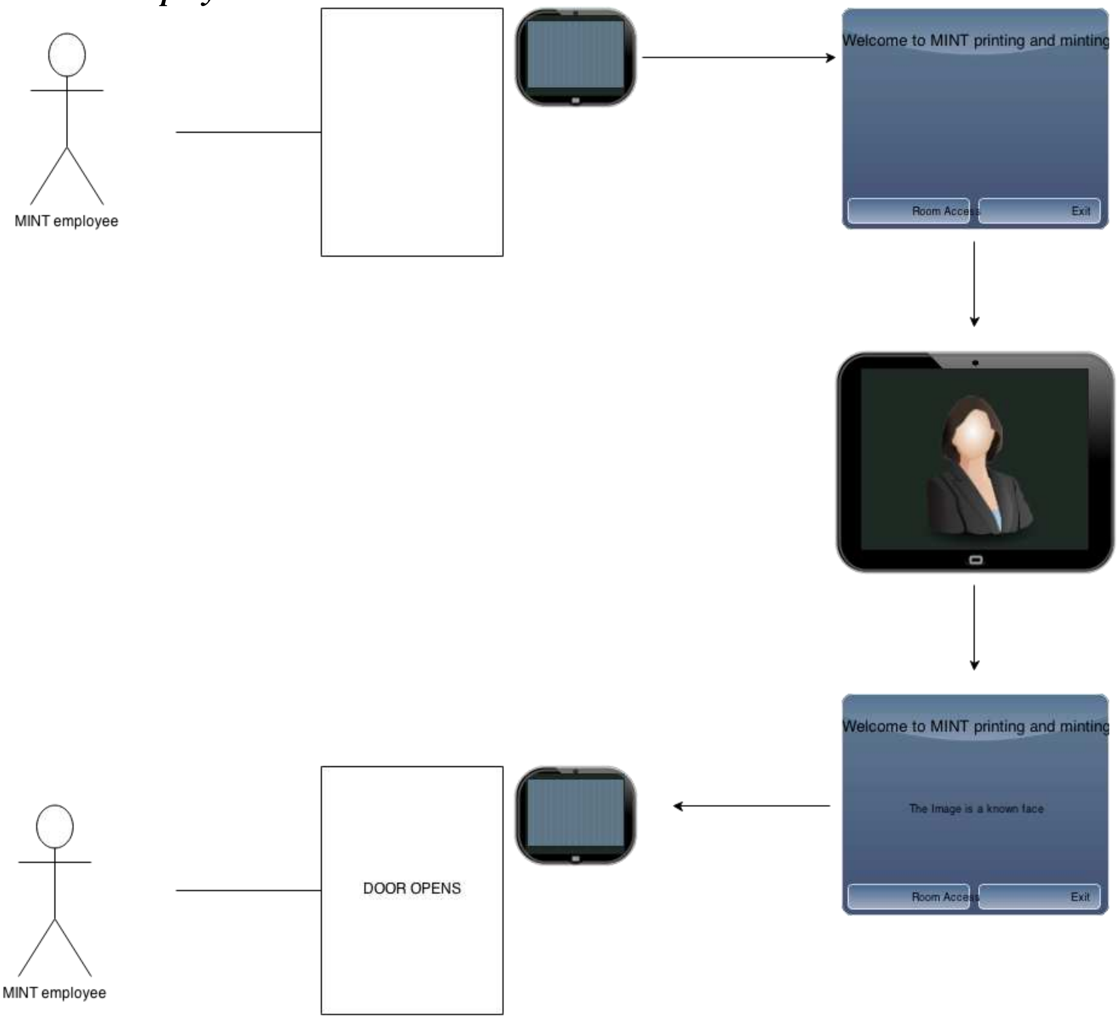


Figure 19: Employee Scenario

4.3.1.2 Imposter

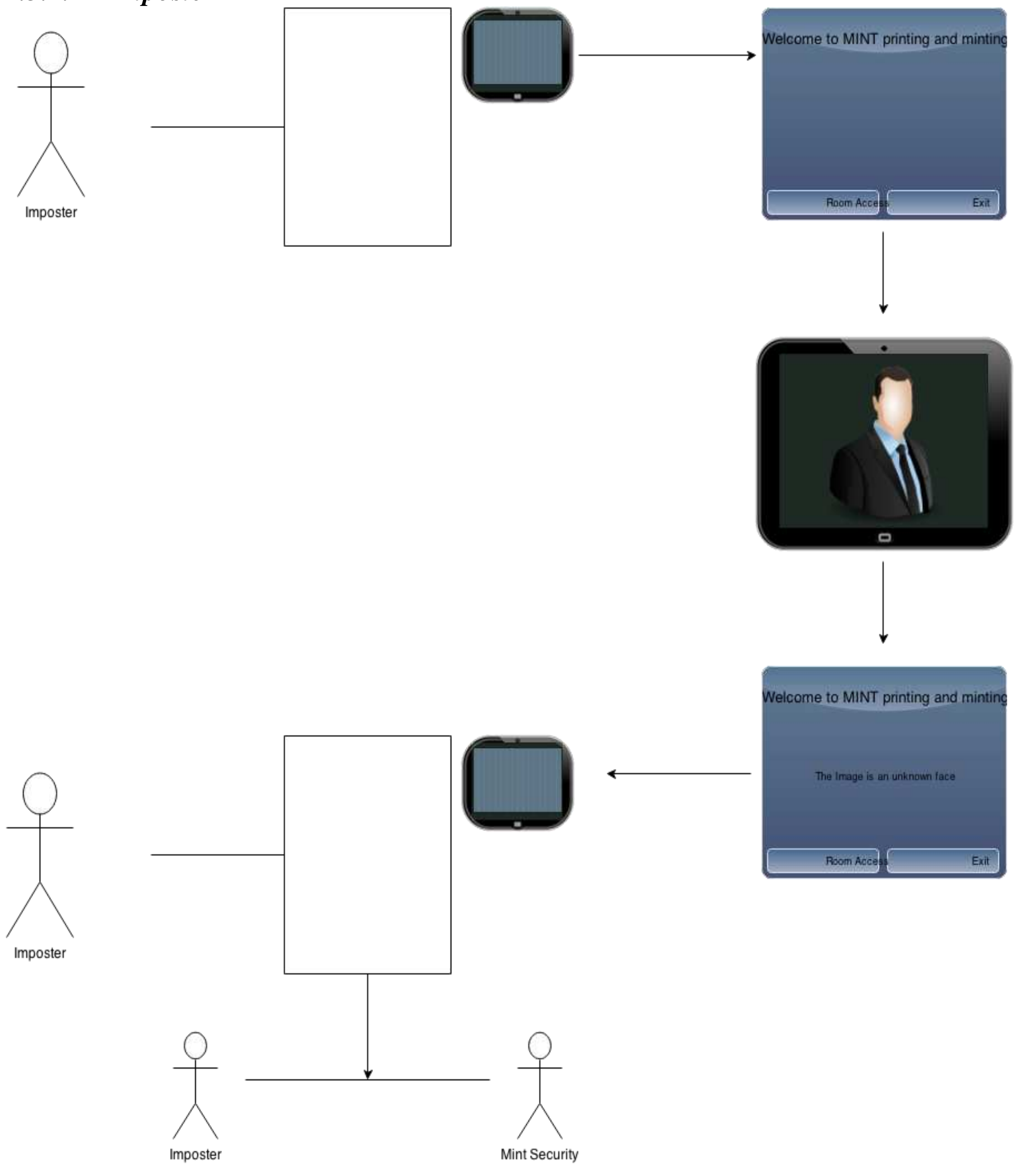


Figure 20: Imposter Scenario

4.4 Sequence Diagrams

4.4.1 Room Access Sequence Diagram

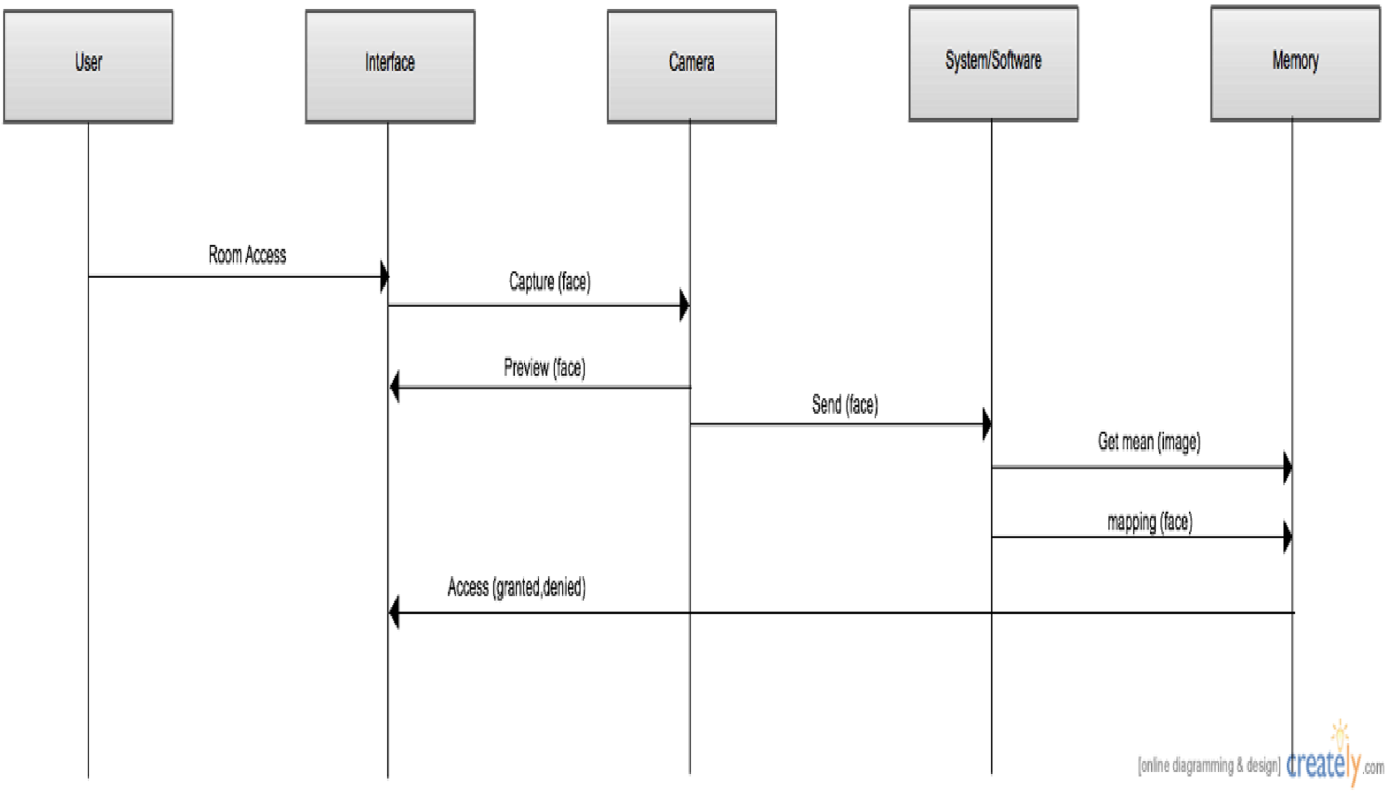


Figure 21: Sequence Diagram 1

4.4.2 Add Image Access Sequence Diagram

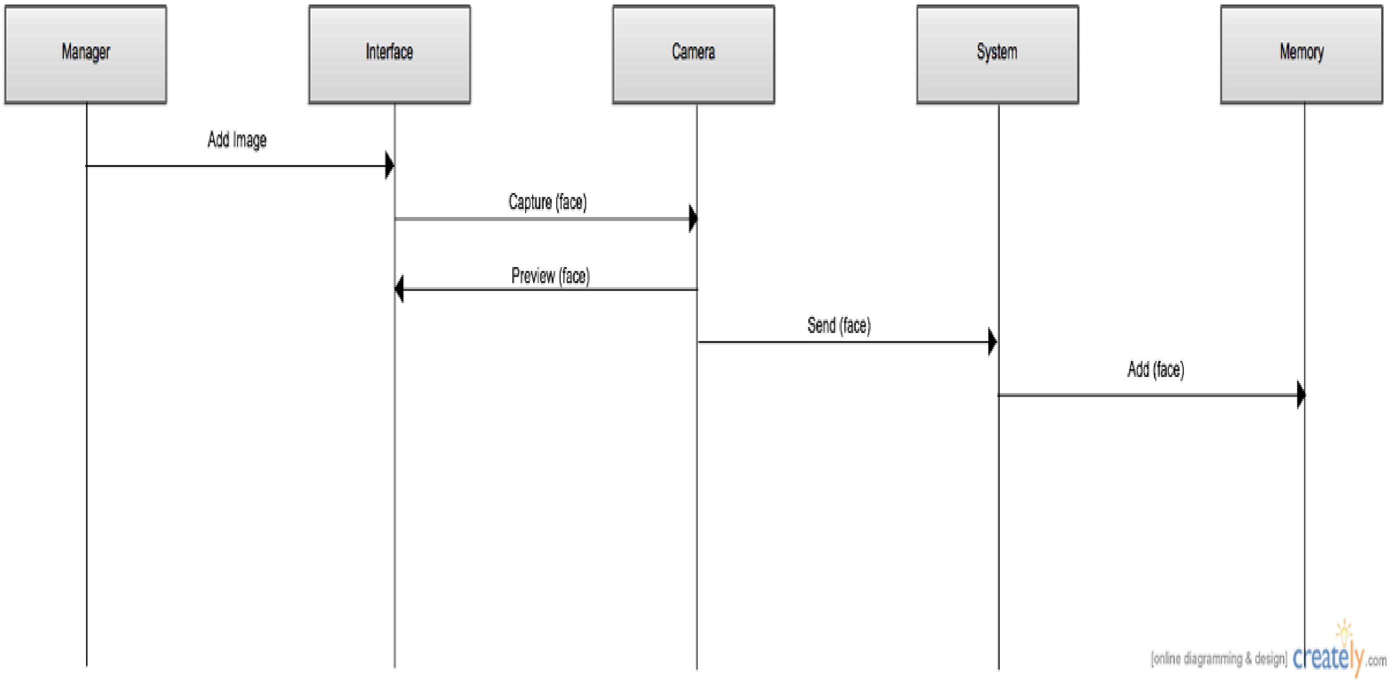


Figure 22: Sequence Diagram 2

4.5 Interface Design

4.5.1 User Interface Design

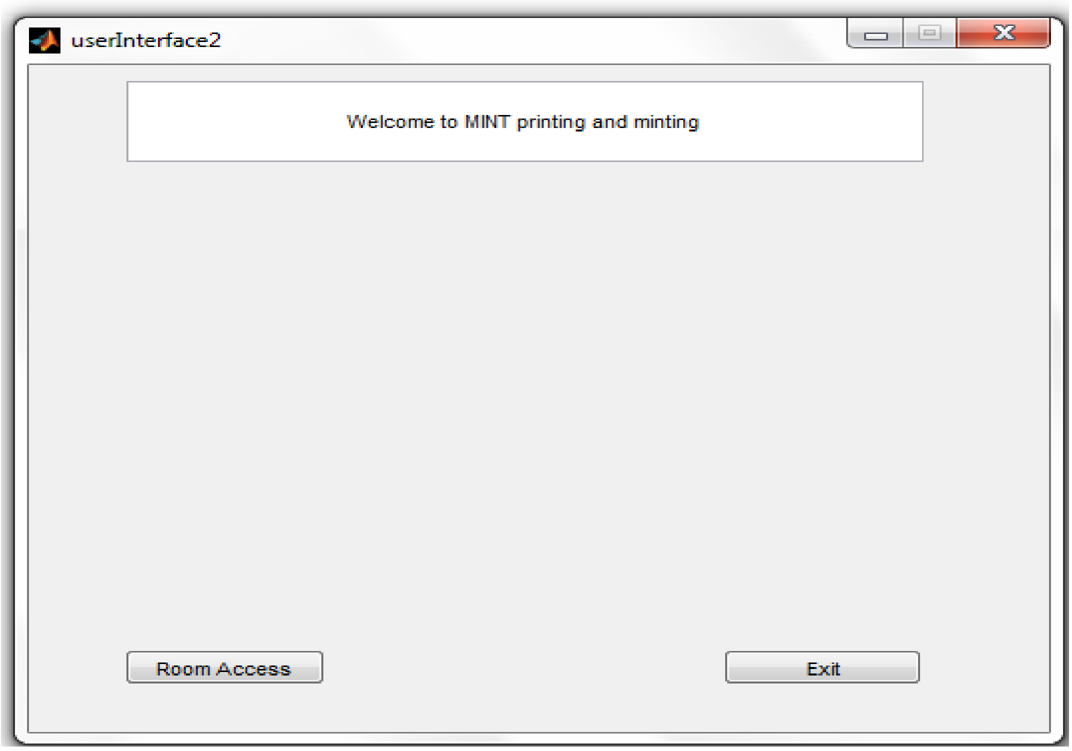


Figure 23: User Interface

4.5.2 Management Interface Design

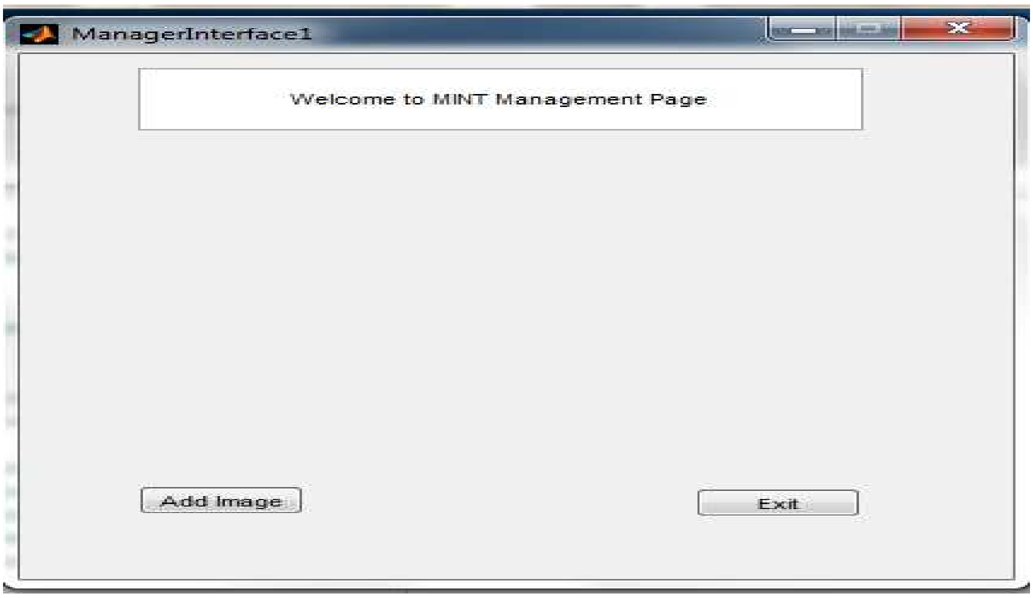


Figure 24: Manager Interface

Chapter 5. IMPLEMENTATION

This chapter presents the implementation aspect of this project. It consists of the code and brief code explanation.

5.1 Code

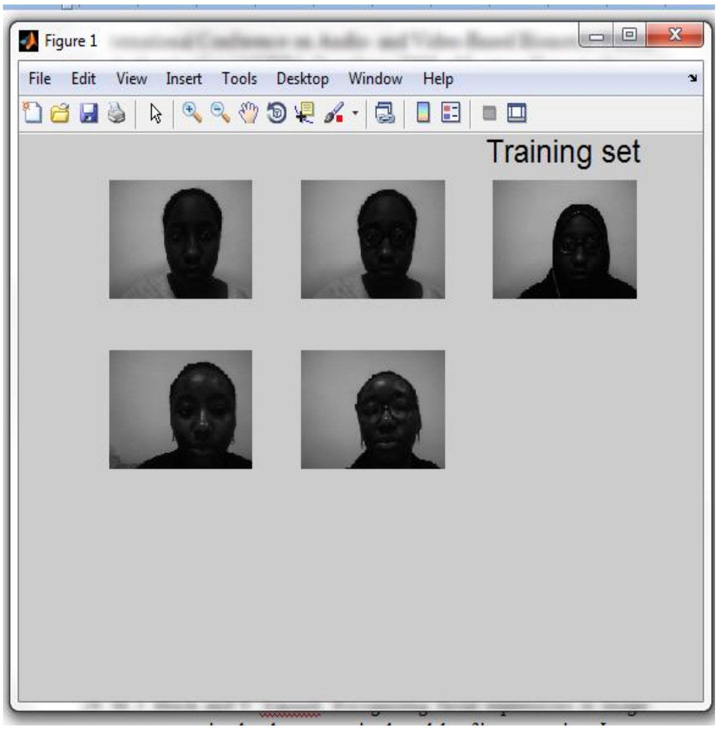


Figure 25: Memory Images

```
S=[];   %img matrix
figure(1);
srcFiles = dir('c:\Project
Images\*.bmp');
M = length(srcFiles)
for i=1:M
    str= strcat('c:\Project
Images\',srcFiles(i).name);
    eval('img=imread(str);');
    blaimg = rgb2gray(img);
    sub-
plot(ceil(sqrt(M)),ceil(sqrt(
M)),i)
    imshow(blaimg)
    if i==3
        title('Training
set','fontsize',18)
end
    drawnow;
    [irow icol]=size(blaimg);

temp=reshape(blaimg',irow*ico
l,1);
    S=[S temp];
end
```

The code above gets the stored images in the memory, converts them from RGB to gray scale and displays the images in rows and columns.

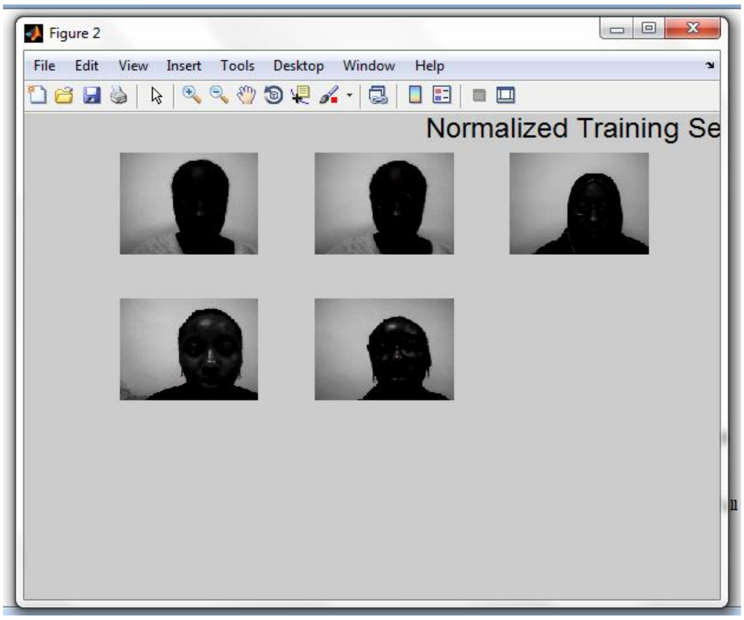


Figure 26: Normalized Version Of Memory Images

```
for i=1:size(S,2)
    temp=double(S(:,i));
    m=mean(temp);
    st=std(temp);
    S(:,i)=(temp-
m)*ustd/st+um;
end
%show normalized images
figure(2);
for i=1:M

str=strcat(int2str(i),'.jpg
');

img=reshape(S(:,i),icol,iro
w);
    img=img';

eval('imwrite(img,str)');
    sub-
plot(ceil(sqrt(M)),ceil(sqr
t(M)),i)
    imshow(img)
    drawnow;
    if i==3
        title('Normalized
Training
Set','fontsize',18)
    end
end
```

The code above changes the mean and STD of all the images, normalizes the images and shows them.

Figure 27: Mean Image

```
m=mean(S,2);
tmimg=uint8(m
img=reshape(tmimg,icol,
irow);     img=img';
figure(3);
imshow(img);
title('Mean Im-
age','fontsize',18)
dbx=[];
for i=1:M

temp=double(S(:,i));
    dbx=[dbx temp];
end
```

The code above calculates the mean image of the memory images

```
dbx=[];
for i=1:M
temp=double(S(:,i));
    dbx=[dbx temp];
end
```

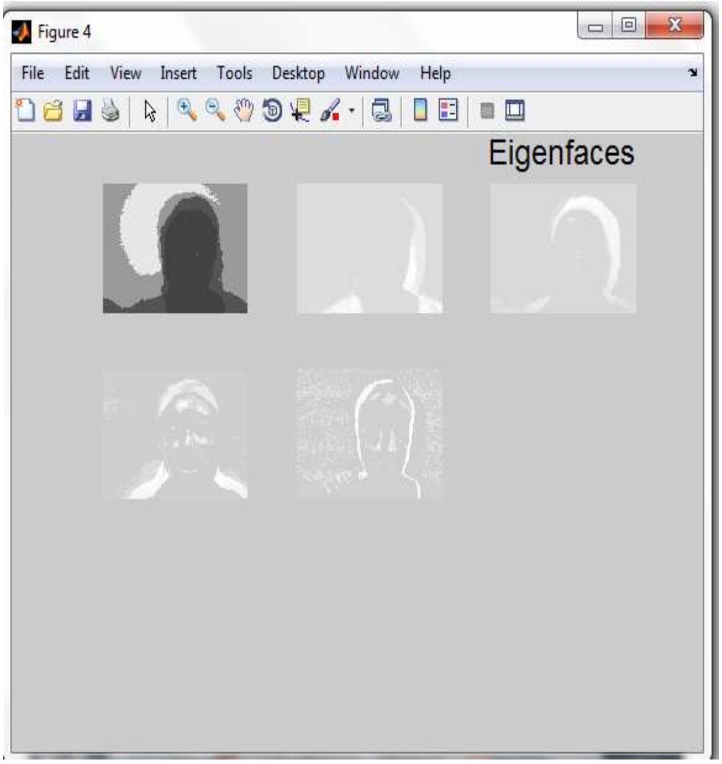
The code above changes the images in the memory for manipulation.

```
A=dbx';
L=A*A';
[vv dd]=eig(L);
v=[];
d=[];
for i=1:size(vv,2)
if(dd(i,i)>1e-4)
v=[v vv(:,i)];
d=[d dd(i,i)];
end
end
[B index]=sort(d);
 ind=zeros(size(index));
 dtemp=zeros(size(index));
 vtemp=zeros(size(v));
 len=length(index);
 for i=1:len
    dtemp(i)=B(len+1-i);
    ind(i)=len+1-index(i);
    vtemp(:,ind(i))=v(:,i);
 end
 d=dtemp;
 v=vtemp;
```

The code above calculates the covariance matrix

```
for i=1:size(v,2)
   kk=v(:,i);
   temp=sqrt(sum(kk.^2));
   v(:,i)=v(:,i)./temp;
end
u=[];
for i=1:size(v,2)
    temp=sqrt(d(i));
    u=[u (dbx*v(:,i))./temp];
end
for i=1:size(u,2)
   kk=u(:,i);
   temp=sqrt(sum(kk.^2));
    u(:,i)=u(:,i)./temp;
end
```

The code above calculates the eigenfaces of the images stored in the memory.




```
figure(4);
for i=1:size(u,2)
    img=reshape(u(:,i),icol,irow);
    img=img';
    img=histeq(img,255);
    sub-
plot(ceil(sqrt(M)),ceil(sqrt(M)),i
)
    imshow(img)
    drawnow;
    if i==3
        ti-
tle('Eigenfaces','fontsize',18)
    end
end
```

The code above displays the eigenfaces of the images in the memory

Figure 28: Eigenfaces Of The Images Stored In The Memory

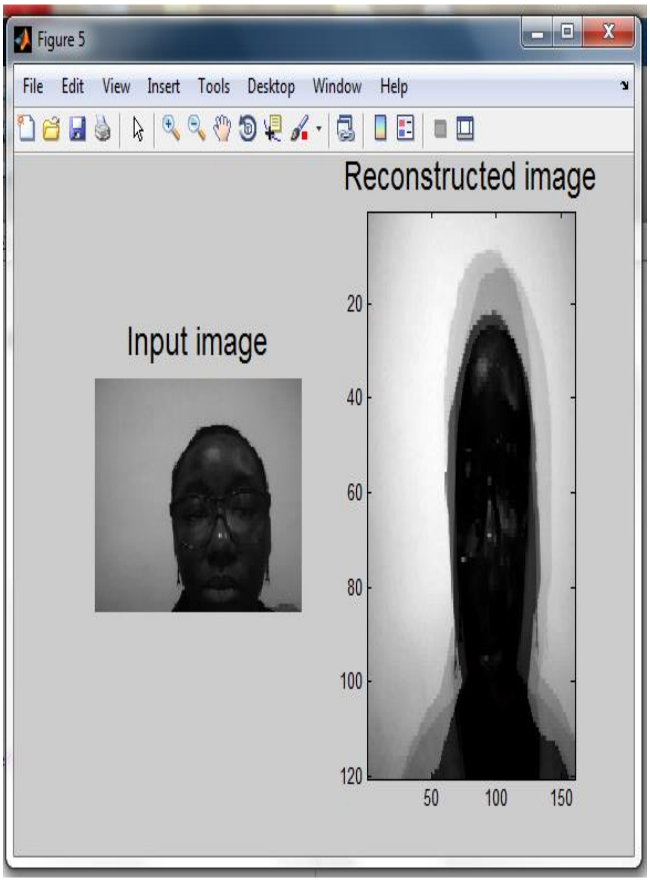
```
omega = [];
for h=1:size(dbx,2)
    WW=[];
    for i=1:size(u,2)
        t = u(:,i)';
        WeightOfImage =
dot(t,dbx(:,h)');
        WW = [WW;
WeightOfImage];
    end
    omega = [omega WW];
end
```

The code above calculates the weight of each face in the training set.

Figure 29: Face Acquisition Window

```
v=videoinput('winvideo', 1);
set (v,'ReturnedColorSpace', 'RGB')
v.FramesPerTrigger= 20;
start(v);
preview(v);
pause(2.0);
im=getsnapshot(v);
closepreview(v);
imshow(im);
acqblaimg = rgb2gray(im);
figure(5)
subplot(1,2,1)
imshow(acqblaimg);
colormap('gray');
title('Input image','fontsize',18)
```

The code above reads an image from the webcam in RGB, converts the image to gray scale, previews the image and displays the image




```
InIm-
age=reshape(double(acqblaimg)',irow*icol
,1);
temp=InImage;
me=mean(temp);
st=std(temp);
temp=(temp-me)*ustd/st+um;
NormImage = temp;
Difference = temp-m;
p = [];
aa=size(u,2);
for i = 1:aa
    pare = dot(NormImage,u(:,i));
    p = [p; pare];
end
ReshapedImage = m + u(:,1:aa)*p;
ReshapedImage = re-
shape(ReshapedImage,icol,irow);
ReshapedImage = ReshapedImage';
subplot(1,2,2)
imagesc(ReshapedImage); color-
map('gray');
title('Reconstructed im-
age','fontsize',18)
```

Figure 30: Input Image And Reconstructed Image

The code above calculates the eigenface of the input image and maps it over the mean image of the images stored in the memory and displays the reconstructed image, which is the image where the eigenfaces are the same.

```
InImWeight = [];
for i=1:size(u,2)
    t = u(:,i)';
    WeightOfInputImage =
dot(t,Difference');
    InImWeight = [InImWeight; WeightOfIn-
putImage];
end
```

The code above calculates the weight of the input image

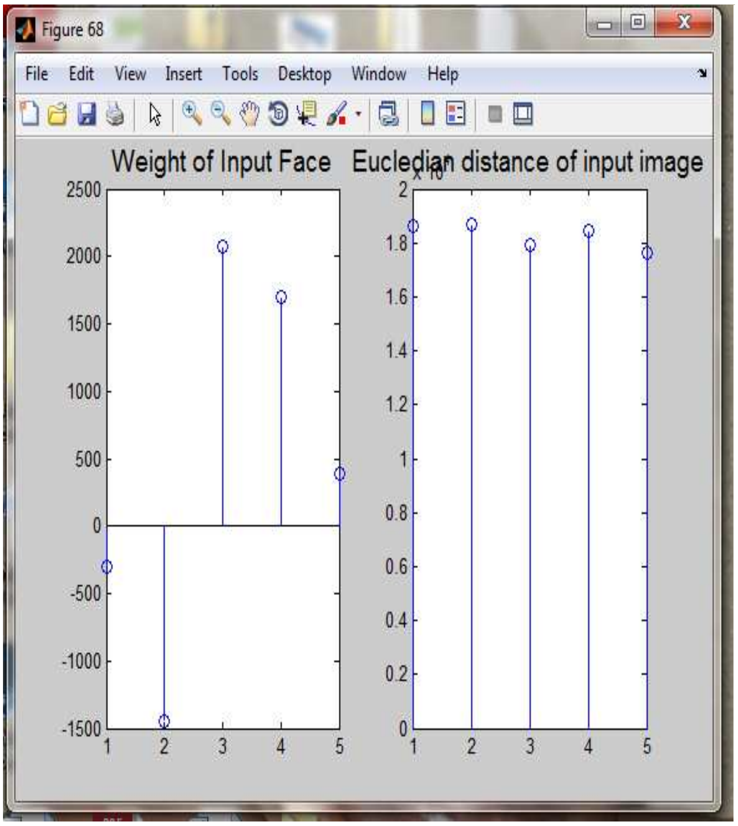


Figure 31: Input Image Weight And Euclidean Distance Graphs

```
ll = 1:M;
figure(6)
subplot(1,2,1)
stem(ll,InImWeight)
title('Weight of Input
Face','fontsize',14)

% Find Euclidean distance
e=[];
for i=1:size(omega,2)
    q = omega(:,i);
    DiffWeight = InImWeight-q;
    mag = norm(DiffWeight);
    e = [e mag];
end

kk = 1:size(e,2);
subplot(1,2,2)
stem(kk,e)
title('Eucledian distance of input
image','fontsize',14)
```

The code above calculates the Euclidean distance of the input image and displays a graph of the weight and Euclidean distance of the input Image

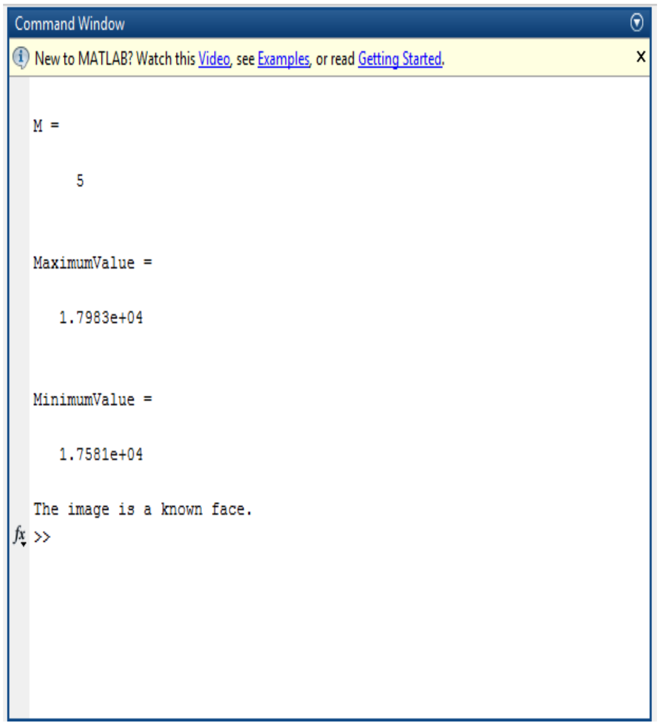


Figure 32: Output Message

```
MaximumValue=max(e)
MinimumValue=min(e)

if (MaximumValue>20000 || Mini-
mumValue < 0)
disp('The image is not a face.');
elseif (MaximumValue<20000 && Mini-
mumValue > 17500)
disp('The image is a known face.');
else
disp('The image is an unknown
face.');
end
```

The code above displays the maximum value and minimum value of the input image.
The threshold in this project is within 20000 to 17500.
If the maximum value is greater than 20000 or the minimum value is less than 17500 a message "The image is not a face." Is displayed.
If the maximum value is less than 20000 and minimum value greater than 17500 a message "The image is a known face." is displayed.
If the maximum value is less than 17500 and the minimum value is greater than 0 a message "The image is an unknown face" is displayed.

Chapter 6. TESTING AND VALIDATION

This is the final phase of the system development. It shows the testing of the code with screenshots.

Testing Output:

Test images 1 are under ideal conditions stated below.

- The lighting is fixed
- The head position is fixed
- No additional information like scarves and glasses

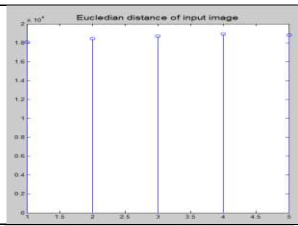
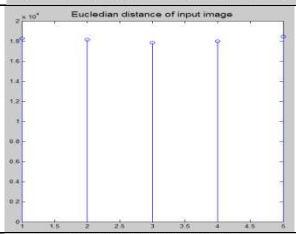
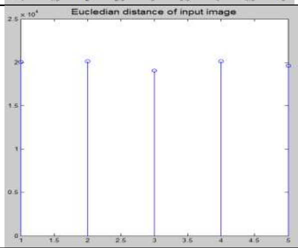
Mean Image	Input Image	Maximum Value	Minimum Value	Euclidean Distance	Output Message
		1.8933e+04	1.8068e+04		The image is a known face.
		1.8378e+04	1.7813e+04		The image is an unknown face.
		2.0143e+04	1.9036e+04		The image is not a face.

Table 5: Test Images 1

Test Images 2 are under the conditions listed below

- The lighting is fixed
- The head position is fixed
- Additional information like scarves and glasses are present

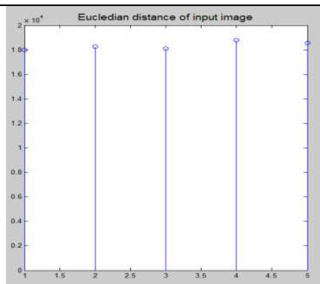
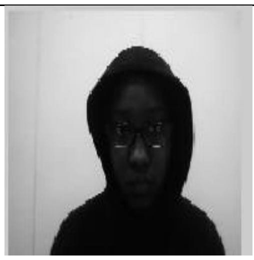
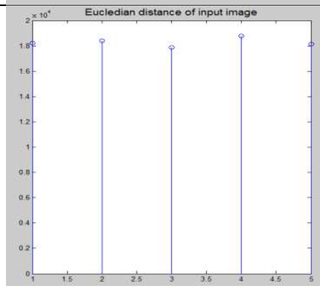
Mean Image	Input Image	Maximum Value	Minimum Value	Euclidean Distance	Output Message
		1.8779e+04	1.7984e+04		The image is a known face.
		1.8793e+04	1.7854e+04		The image is an unknown face.

Table 6: Test Images 2

Chapter 7. CONCLUSIONS AND FUTURE RECOMMENDATIONS

MINT is an important organization in Nigeria's economy it deals with the securing of highly secured documents, printing and minting of Nigeria's currency (Naira). The current security system is based on signing in and out on paper does not live up to its expectations; that is why I came up with an idea for facial recognition as a form of password for MINT, to increase the security level at MINT. Face recognition is a biometric that has taken the world by storm. It is an interesting and intriguing aspect of biometrics. It is a broad field but in this paper we briefly discussed it. There are three different approaches of facial recognition, which are holistic methods, feature, and hybrid methods. There are several face databases that are publicly available such as AR Database, BANCA Database, CAS-PEAL Database, and FERET. There are various techniques for facial recognition, but this paper focuses on the eigenfaces technique used for facial recognition, it is evident that eigenface produces amazing results but under environments with constraints.

First part of senior project only covers the understanding of problem, literature review and deep analysis of problem. Second part of the senior project includes the implementation and testing of system.

There were various difficulties faced throughout this project. The biggest challenge faced was learning MATLAB on my own, unfortunately I did not know anyone who could help me with image processing in MATLAB but with tears, hard work, determination and words of encouragement from my family and Dr.Nighat I was able to learn bits and pieces. I will not say I know a lot but I will definitely say I have learnt enough for this project. Understanding the calculations and the code was also an issue; at first the code was working fine but once I started making changes the output went haywire. Understanding and conquering the constraints related to face recognition like light, background and head position was also another issue, as I had to change the laptop I was using to accommodate the changes and the calculations. Another setback was time constraint, as I had other courses their assignments, midterms, quizzes and projects to work on. I honestly think I could have done a better job if I did not have other courses to worry about during the semester. Face recognition is a huge subject and for this project just one aspect of it was touched upon in the future the other aspects will be added. Face detection and face extraction are the aspects that will be added because they will help in making the system more accurate. Using a database instead of a folder is something that I am planning on doing, which is an upgrade for the memory. Calculating the threshold is also something that will be added in this project instead of manually calculating and changing the threshold in respect to the situation. The implementation analysis is also something that will be done in the future, because the system has to work under the environmental conditions at MINT. Changing the system from a holistic method to a hybrid method is also something that will be done in the future. The overall experience of this project was exciting, frustrating, fun and challenging. It was a mixture of emotions and definitely a lifetime experience.

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