Thermal Face Recognition

by

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Abstract

Face Recognition systems has been rapidly developing and widely used. They usually depend on the use of visible images but these systems are still subject to illumination problem and face poses. To address such problems, thermal face recognition has been recently receiving much attention[1]. This project aims to develop a thermal face recognition system which could be used as a door access control for important rooms/buildings. This system consists of image segmentation, feature extraction, and classification. In the segmentation, Adaptive Threshold algorithm in used in segmenting the face region from the thermal image. In the features extraction, KAZE algorithm is adopted. While in the classification, the Neural Networks algorithm is applied. The proposed system is implemented using OpenCV and C++ and it is evaluated using an available online database called Terrarvic IR Database[2], which contains more than 2000 thermal face images for different persons with different poses. The experimental results, under different designed scenarios, showed that our system can achieve an accuracy up to 93.3

Acknowledgments

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Chapter 1

Introduction

In the past, classic face recognition was widely used in many real world applications, however; it faced many problems such as head pose, position, facial expression and also the image has to be well lit [3],[4]. Thermal imaging was employed to solve these problems [5], because it works based on the fact that there is infrared energy that is being emitted from every object depending on its temperature and characteristics, and of course, this includes the human face which makes this energy unique for each different person[6].

1.1 Project Objective

Develop a system that will be able to recognize human faces based on their thermal images after making a comparative study between the algorithms that have been used in related systems and testing them on our database to come up with the best algorithm that can be used in real-time and have the best accuracy.

1.2 Deliverables

Developing an application that can be specialized in making universities control rooms more secured by having a thermal face recognition system that allows desired people to enter the rooms based on their authorities.

Chapter 2

Thermal Face Recognition using Neural Networks

2.1 Related work

1- Thermal face recognition using convolutional neural network, IEE 2016. [7]

Mentioning that similar work used some of the traditional thermal recognition methods which requires more efforts from human to select and extract features, they faced some problems like the improvement of recognition rate, the methods were not capable enough to describe the details; or even traditional methods that have some shortcomings such as the complicated process. Alternative method Convolutional Neural Network(CNN) is a deep learning algorithm, it has been proposed because it can automatically learn new features from raw data, also it combines features extraction and classifying into one step that can reduce the workload for the humans. In a multi-layer neural network architecture, each node undergoes some calculations and serves the next node with them, each node's value is relevant to its previous node.

In Convolutional Neural network, is can optimize the normal neural network structure (9 layers). To test the CNN model, The RGB-D-T Face Database was used, its images were collected from different types of cameras. Images were taken of 51 students with respect to three main aspects; head rotation, facial expression and illumination variation.

So 100 images for 51 students with 3 aspects, there are 15300 (51x3xl00) images in the database to be trained and tested with.

"The proposed CNN has nine layers; Convolution layer 1 employs 64 different convolution kernels whose output image is 56x56 in size. The output data of max pooling layer 1 are decreased into 28x28, which undertakes down-sampling. The fourth layer is mainly to perform normalization, which is advantageous to the data in the form of image. Then, the data are convoluted and pooled twice, whose dimension and size become 128 and 7x7. Finally, the data are grouped into 51 class. The structure and the output size of each layer are summarized in the figure below."

Layer	*Output*
Images data	112×112
Convolution layer 1	64×56×56
Pooling layer 1	64×28×28
Norm layer1	64×28×28
Convolution layer 2	128×28×28
Pooling layer 2	128×14×14
Convolution layer 3	128×14×14
Pooling layer 3	128×7×7
Classifier layer	51×1×1

Figure 2.0: Number of outputs for each layer

	Head Rotation	*Expression*	*illumination*
LBP	79.33	96.27	98.35
Moment Invariant	59.37	91.76	94.51
HOG	90.27	98.78	99.18
Our Method	98.00	99.40	100.00

Figure 2.1: Comparative between similar algorithms and their method

Experimental results had been done and compared with three competitive algorithms which are; LBP, HOG, Moment Invariant. It showed that with due to respect of the three previously mentioned aspects, head rotation affects the most in the recognition rate of the images, whereas illumination variation has the least effect of the three on the rate. In table II, a comparison has been done to show the results, and it shows that CNN outperforms the three other algorithms in the recognition rate.

This paper is based on work that is very similar to our project idea, and we think comparing our work to theirs and having them as a reference will be very helpful for us.

2- Human Thermal Face Recognition Based on Random Linear Oracle (RLO) Ensembles[6]

They started talking about classic face recognition where there has been remarkable progress in it. However, they faced many problems like image variation due to many differences in head positions, expressions and poses. So infrared image recognition has been employed to solve this problem, at the beginning it has not received much attention due to many limitations, but recently these limitations are being broken one by one and they can solve the problems classic face recognition faced. Mentioning that every person has a unique thermal signature for him depending on temperature and characteristics.

Improving the recognition rate based on Terravic Facial IR Database was their main motivation to work on. Similar works have been done before, in [8], PCA has been used for dimensionality reduction, and then two different classifiers have been used to identify the image. Based on Terravic Facial IR Database, recognition rate reached 94.11 percent. In [8], Wavelet transform has been used for features extraction, then providing them to the classifiers. Based on Terravic Facial IR Database, recognition rate has reached 93 percent.

This paper proposed an approach with two variants based on Random Linear Oracle Ensembles (RLO). Segmentation based Fractal Analysis(SFTA) algorithm was used for features extraction, then RLO ensembles was used to recognize the face from its thermal image. For the dimensionality reduction, one variant (SFTALDA-RLO) was used the technique of Linear Discriminant Analysis (LDA) while the other variant (SFTA-PCA-RLO) was used the Principal Component Analysis (PCA).

The proposed model consists of two phases; training phase and testing phase. In the training phase, the training data or images are collected, then (SFTA) algorithm is used to extract features from every one of them, then PCA and LDA are used for dimensionality reduction which are used to build the RLO model, which is later on used in the testing phase. In the testing face, the unknown or test image is captured, extracting features from it using (SFTA), then project the extracted features from the dimensioned vectors from the training phase and match them with the results.

Experimental results, the Terravic Facial IR Database was used to evaluate our two variants. The dataset set consists of 20 classes with greyscale images (360 x 240) and each class represents one person. In this paper, we have used 17 classes as three classes were corrupted. For each class, 200 grey-scale images were used.

3- Real-Time Efficient Parallel Thermal and Visual Face Recognition Fusion [10]

Most of the decision fusion techniques are computationally expensive, same as Gabor filter since it requires high computational requirements, So this paper decided to use a parallel solution which is fast and efficient.

They started discussing Gabor Filter For face recognition, One of the most successful recognition methods is 2-D Gabor Filter[14] which states :

$$R1 = x\cos(\theta) + y\sin(\theta)$$
$$R2 = -x\sin(\theta) + y\cos(\theta)$$

$$R(X,Y,\theta,\lambda) = \sum_{x=-X}^{N-X-1}\sum_{y=-Y}^{M-Y-1} I(X+x,Y+y)f(x,y,\theta,\lambda)$$

They chose the feature point in a particular window of size SxT where
$S = N/\sqrt{W}$ and $T = M/\sqrt{W}$

Architecture of Visual, Thermal and Fuse data Fusion. Each of them has four main processing sub-modules :

- o Feature value calculation
- o Feature vector selection
- o Similarity calculation
- o Decision fusion

Decision Fusion Architectures :

They used a much flexible decision fusion as proposed in [15] for the combination of Visual, Thermal and Data Fused Face Recognition. Figure 1 shows Decision Fusion Face Recognition Architecture.

The below table shows that the accuracy of decision fusion is greater than without any fusion:

Input Type / Accuracy of Resolution	21x30	37x49
Thermal	38%	38.6%
Visual	63%	74.38%
Decision Fusion (Visual and Thermal)	86%	97%
Decision Fusion (Visual, Thermal and Fused Data)	97.11%	98.6%

Figure 2.2: Accuracy of decision fusion

Parallel Architecture has its own Resource Requirements, for example a parallel code that runs in 1 hour on 3 processors actually uses 3 hours of CPU time, also memory for parallel recognition is bigger than normal one, moving to its benefits, Parallel Face Recognition speedups performance to three times that of sequential face recognition , also it's portability since it can be run on LAN and no special arrangements would be required.

DATABASE

Experiments were performed on database called Equinox includes 24 persons, each has 3 images (Thermal, visual and fused) with frontal illumination [16].

4-Fusion Based Approach for Thermal and Visible Face Recognition underPose and Expressivity Variation [17]

In this paper the researchers investigate the combined advantages of thermal and visible face recognition on a Principal Component Analysis (PCA) induced feature space. Recognition is done with k-nearest classification.

The basic PCA approach to Face Recognition is often used for data analysis, it offers solution of reducing a complex data to set a lower dimensional one. It firstly explored by Turk and Pentland[13]. Goal of PCA is to derive another matrix P which will describe linear transformation.

We compute matrix as follow:

$$M = \frac{1}{S}\sum_{i=1}^{S} X_i \ .$$

Then Subtract the mean face:

$$H_i = X_i - M \ .$$

Compute the covariance:

$$C_A = \frac{1}{S-1} AA^T \ .$$

As for Classification, they used K-NN Classifier with Euclidean distance, to build it they needed to define the number of classes C, to form a labeled training set of N samples. The algorithm need to follow those steps:

a) Compute the distances for each prototype.

b) Sort the distances increasingly.

c) Assign to W (vector) most frequent from the class sort array y1,y2,y3,..

Figure below shows the fusion scheme (A) PCA-based face recognition in visible spectrum; (B) PCA-based face recognition in IR spectrum(C) Score fusion of (A) and (B).

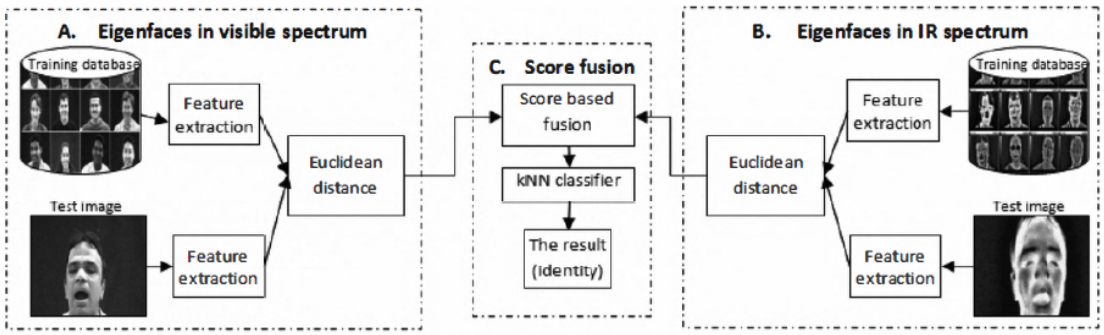


Figure 2.5: Face Recognition in visible and IR spectrum

A- Computing the Eigenfaces from the visible images.

B- Computing the Eigenfaces from the IR Thermal Images.

C- The Score Fusion Scheme.

DATABASE

As for database, they used 3 databases

a) OTCBVS benchmark[4]

b) Notre IR Database [17]

c) Equinox IR Database [16]

For training Sets they used Notre IR Database, as for Testing they used Equinox IR Database, but for their experiments they used OCTBVS benchmark which contains 4228 pairs of visible and IR Thermal Images

They used for training set a total of 12 nearly frontal images for each subject 6 images in IR Spectrum and 6 images in visible spectrum, for each spectrum there are 3 images under the "surprised" and 3 under "Laughing", and 11 positions for each type of acquisition as in Fig. 3 below)

This figure is an example of an subject under pose variation: Visible Spectrum images and IR Thermal images

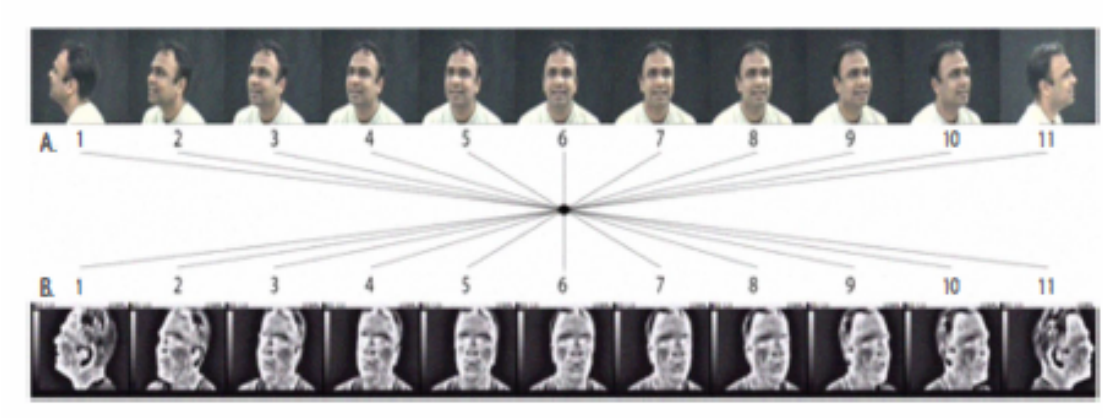


Figure 2.4: Visible and Thermal Spectrum

RESULTS AND TESTS

They ended up that recognition for the IR Spectrum is lower than the visible Spectrum, they also saw that for the 1-NN Classification had a superior results in all test that achieved 100 percent recognition in some tests(test 4). Moving on , the recognition rate for the classical PCA-base approach is as poor as 69.10 percent and their fusion based approach improves the recognition rate with almost 6percent. So at last their fusion based approach exceeds the individual performance of the systems with almost 10 percent.

Below Tables are the results for 1 ,3 ,5 and 7 k-NN Classifier with the 3 views (Visible , IR and Bimodal)

1-NN

	Visible	IR	Bimodal
Test 1 rates(%)	91.66	73.80	96.42
Test 2 rates(%)	95.08	87.05	98.21
Test 3 rates(%)	89.28	62.50	92.85
Test 4 rates(%)	99.10	92.85	100
Test 5 rates(%)	69.10	53.72	74.85
Test 6 rates(%)	75.89	56.25	82.73

Figure 2.5: KNN Classifier results based on K

So, from those tables there is an obvious result which is using 1-NN classifier in Bimodal has the highest and best rates in recognition.

5- Thermal human face recognition based on GappyPCA [20]

They have proposed a Gappy-PCA thermal human face recognition technique for frontal face only. The results obtained on testing sets about 98.61 Percent correct recognition

- Researches use infrared images for face recognition until they come up with better system performance because the use of thermal face images is better than visual images.

1. Infrared camera captures energy from the object surface
2. Thermal images do not depend on illumination
3. Face detection, location and segmentation are easier and more reliable for thermal face images then their visual images

- The problem can be classified into two categories:

1. Feature based : find geometrical features from the face
2. Holistic methods : Judge the global properties of the human face pattern

Proposed Approach

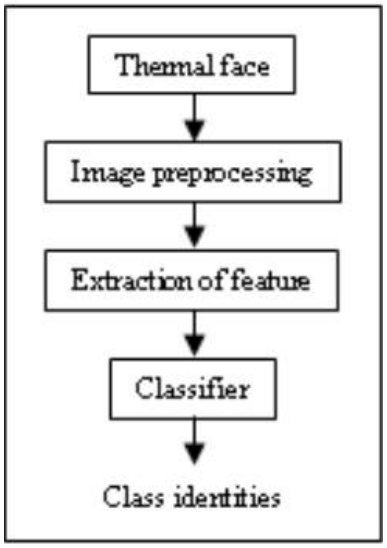


figure 2.6: Proposed Approach

- Preprocessing : they covert each color images into grayscale images and then convert the grayscale images into their corresponding binary counterparts (Connected component labeling algorithm: used to extract the largest component

from the binary image) Then they used Bresenham ellipse drawing algorithm to crop the human face in elliptical shape

Principal Component Analysis (PCA) is used in the problem of contaminated pixel. But it can't restore the missing information so they use GPCA approach to store the statistical information that is missing in the PCA

- Extraction of features: In every gray scale image, each pixel is represented by 8 bits; the range of intensity value is 0 to 255 Each image of the images is transformed into horizontal vector to get the "n-dimensional vector"
- Classification: Linear regression based classifier (LRC) is used for classification, LRC has less limitation than the artificial neural network (ANN) and support vector machine (SVM) LRC is simple and use easy calculations and faster than the other algorithms

EXPERIMENT AND RESULTS

FLIR 7 CAMERA is used in the experiment. 12 Frontal images are taken in each person Image size 112*92

- Experimental process divided into two ways :
    1. Simple approach features are extracted before the restoration process, total images are testes using 2-Flod and 3-Flod
    2. GPCA based approach is used to get the better performance and to restore missing thermal pattern
- GPCA gives better result compared to the simple approach under both the 2-flod and 3-flod The highest percentage of recognition rate is 98.61 under 2-flod cross validation

Future Work : In future, authors will treat detection of facial expression as a separate problem. Authors will also consider pose changes of subject for their experiments in future. Temperature variation may create different thermal pattern of the same face image

6- Thermal infrared face recognition based on lattice computing (LC) techniques [21]

- They proposed a human face recognition system that carries out four information-processing tasks:
    1. Image acquisition : Carried out by the camera hardware
    2. Face localization : Carries out stable robust face localization in the sense that is clearly separates the face from the background (Viola-Jones face detector or Alternative face detector)
    3. Feature extraction : Carried out using orthogonal moments
    4. Classification : Carried out using techniques from the lattice computing framework (LC)
- In Face localization they used five methods
    1. image is converted to Gray scale
    2. Image Binarization : They convert the gray scale image to a binary image to get all the useful face information
    3. Morphological Opening and Center of Mass Computation
    4. Ellipse Masking
    5. Face Cropping

They carried out feature extraction by computing orthogonal moments (ZMs And TMs) on the cropped image with a capacity to encode image content with minimum redundancy

They used MATLAB platform to implement their software and "The Terravic Facial IR benchmark Dataset", The database includes images of 20 persons . 700 images for the first 10 persons (total 700 images) 690 of them were used for testing and the other 10 were used in training Local Binary Patterns (LBP) ins used for the temperature distribution the images.

Method	Features Type	Classifier Type	Recognition Rate (%)
[30]	CoG	MDC	85%
[28]	LBP & PCA Wavelets & PCA	MDC NNs	94.11%
Proposed	TMs	LC-MDC	95.43%

Figure 2.3: Proposed Method Result

Their best results were 95.43 Percent while using LC-MDC Classifier and TMs Feature as explained in table below.

2.1.1 Similar System Description

There are many efforts that had been done in thermal face recognition, but we have limited the similar systems to these two [1],[6] because they are the closest efforts to our project.

In [6], the paper proposed a model based on thermal face recognition based on Segmentation based Fractal Texture Analysis (SFTA) to extract features from the faces, and Random Linear Oracle(LRO) to recognize the face from its thermal image.

In [1], they proposed a Convolutional Neural Network(CNN) method for thermal face recognition with respect to head rotation, expressions, illumination variation. And compared with traditional recognition methods, the proposed system can produce the best recognition results and it suggests that this method is a very promising one that can be used in under extreme conditions and still produce the best result.

2.2 Motivations

- Implementing the method on dierent poses and other benchmark databases [9].
- Considering pose changes of subject for their experiments in future[10].

2.3 Proposed system

We presented a system called Thermal Face Recognition system. Thermal Face Recognition can be used and implemented in many real world applications. Based on a survey that has been done, this project can be most usefully in identifying faces in security[11]. With the system's ability, the system that will be able to recognize faces based on their thermal images in universities' control rooms in order to be more secured by having a thermal face recognition system that allows desired people to enter the rooms based on their authorities.

2.3.1 System Overview

First, the thermal image camera provides the system with the needed thermal images of the desired person who wants to have an access to the room. The system segments the input image and extract features from it using KAZE algorithm. These features are compared with the already stored ones in the database and classify the input image using Neural Networks.

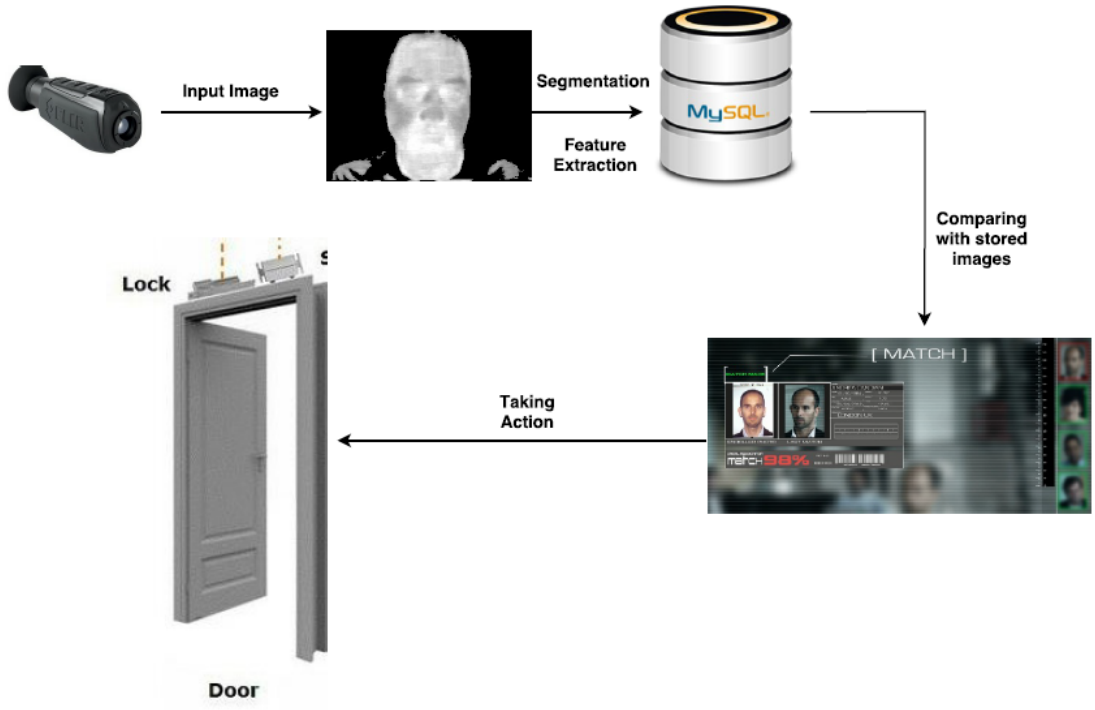


Figure 2.6: System Overview

2.4 Details and technical aspects

A. Segmentation

In computer vision, image segmentation is the process of partitioning a digital image into multiple segments (sets of pixels).The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze [12].The simplest method of image segmentation is called the thresholding method. This method is based on a threshold value to turn a gray-scale image into a binary image. In our case, this threshold value is calculated based on the average of the images' pixels, if the pixel is greater than the threshold value; it is assigned to the maximum grey value, else; it is assigned to the minimum grey value. After completing this, now the thermal image is converted into a binary one (black and white), and the thermal face is distinguished from the rest of the image having the large white area. These white pixels (the face region) are

then restored from the original image's pixels to get the original face from the thermal image not the binarized one in order to process on the face area or region only. After restoring the face's pixels, there are a lot of black pixels still remained in the image, in order to remove these pixels; the white pixels are stored in a vector, discarding the black ones. Then the image is returned with the area of interest which is the white pixels.

If g(x, y) is a thresholded version of f(x, y) at some global threshold T,

Simple threshold function pseudo code[13]

```
if src(x,y) ¿ thresh
dst(x,y) = maxValue
else
dst(x,y) = 0
```

B. Feature Extraction

Facial feature extraction is considered the vital part in the recognition process as it is the stage where every image or face is analysed and applying different algorithms on them in order to differ each one from another to be used later on in the classification stage. In our project we used 4 algorithms and compared between them to get the best accuracy (Hog, Gabor, Thermal Features and Sift)

1) Histogram of Oriented Gradients (HOG): a feature extraction algorithm where we extract the feature descriptor from our images, by calculating the vertical and horizontal gradients and by also using sobel algorithm to help us getting the same results as the descriptors[13].

2) Gabor: We did try using Gabor Algorithm which is used for edge detection. Gabor filters are similar to those of the human visual system, alse it can be viewed as a sinusoidal plane of orientation and particular frequency.

3) Thermal Features: In the part of the thermal features, we use the pixels of the input image as features, but it must be taking by a thermal camera also high resolution of imaging refers to the details in the image, as the image contains a larger number of features.

4) Sift : It is used to detect the local features in the images. used in many application such as object recognition and image stitching. it transfer the image pixels to many feature vector which share similar properties and then start its own work on this local features.

5) Kaze : A novel 2D multi scale feature detection in a nonlinear scale space. Previous methods at different scale levels by building its own Gaussian scale space of the image.

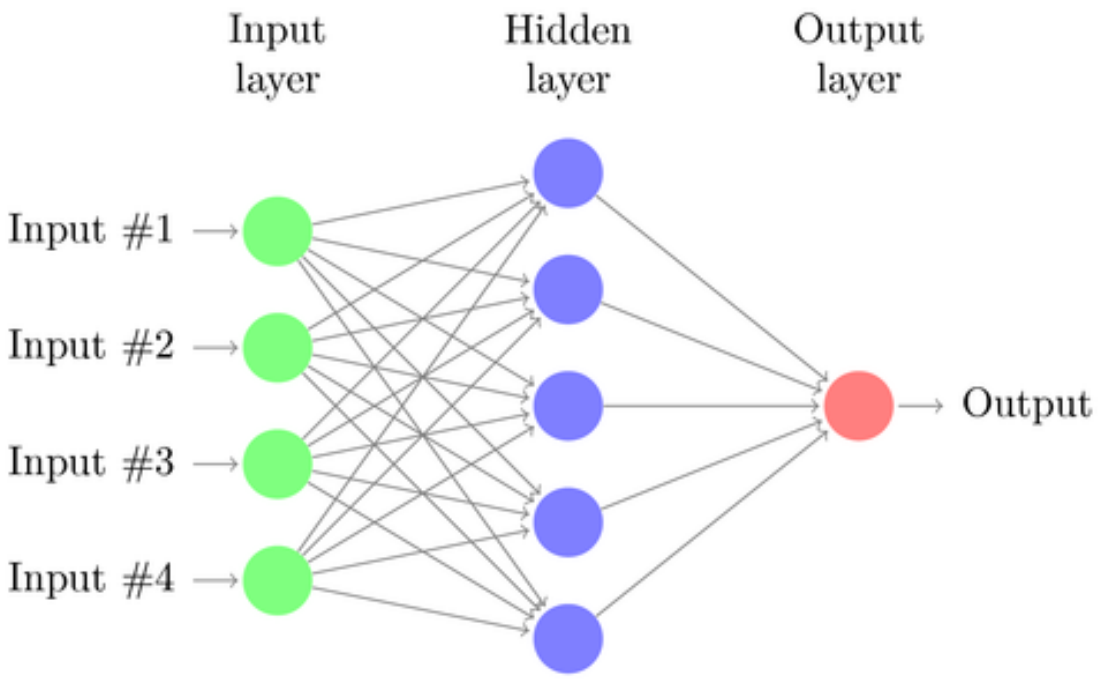


Figure 2.4: Neural Networks model

C. Classification

Classification is dividing certain data into categories or classes, to be used in it's most effective way, which helps in retrieving certain data from the whole dataset in accurate way. One of the strongest Classifiers and the one we used is Neural Network. A Neural Network is consisted of 3 main layers : 1) Input Layer - 2) Hidden Layer and 3) Output layer Input Layer takes the input data , send it to the hidden layer which here the calculation and the network starts learning , then the output layer which gives the class related to the input. So here is how Neural network works, by using the concept of hidden layers[22]:

but Neural network has different types , we are using Multilayer perceptron supervised Neural Network.

Multi-layer Perceptron (MLP) is a supervised learning algorithm, it utilize a supervised learning technique which is back-propagation , it consists of multilayer nodes all fully connected except the input nodes.

The same normalization equation for input values is used for output values while training

the network.

After all that we create a Confusion Matrix,A confusion matrix is a table that helps the classifier to be more accurate, it consists of True Positives, False Positives , True Negatives and False Negatives.We can easily calculate the accuracy, that is the ratio of correctly predicted samples, by simply summing the diagonal of our confusion matrix (number of correct predictions) and diving by the sum of our cells of our confusion matrix (number of test samples)

Let's now define the most basic terms, which are whole numbers (not rates):

- **True Positives (TP)**
- **True Negatives (TN)**
- **False Positives (FP)**
- **False Negatives (FN)**

  After reading the test data , it has it's own Confusion matrix, then we compare between them getting the accuracy by incrementing the prediction based on getting true for every yes and no we predicted in its own place.

2.5 Summary

We developed a system called Thermal Face Recognition that can be specialized in granting access to universities control rooms by recognizing the authorized people to access these people based on their thermal images. There are two main stages in the system;

- User Enrollment:

In this stage, the admin/s who will be specialized in managing the system, will be having the privileges to add new members into the system by adding their names, authorities and their thermal face images to be trained by the model.

- System Testing:

This stage is composed of three main steps;

1) Segmentation: Where the images are segmented to be focusing on the face region only not the whole image discarding the background distractions to increase the accuracy.

2) Features Extraction: In this step, a feature extraction algorithm, which is KAZE in our system, is applied to each image in order to extract its own unique local features that differs it from other images and other persons. These features are stored together in order to build a model to help recognizing the faces in the classification stage.

3) Classification: In this step, the recognition of the faces happens, where the desired image or face is being tested and predicted to the closest person in the already trained model to decide whether to grant access to this person or not.

Chapter 3

Proposal Document

Abstract

The main idea of this project is to study Face recognition using thermal signatures of the human person, by detecting the face of the person, extracting some features from it and finally classifying the face to to tell whose face it is. Many algorithms have been used before, so making a comparative study to decide which algorithms we are going to use will be our main objective to come up with the best recognition rate testing on available online thermal datasets. After making the comparative study, our application will be used in universities control rooms to decide whether to grant access to the desired person or not based on his thermal face.

3.1 Introduction

3.1.1 Problem Definitions

As mentioned, classic face recognition has faced many problems due to many variables such as facial expressions, head poses and illumination invariant. So thermal face recognition was employed to contribute solving these problems. Similar works had been done before. And they also faced some problems in different poses of the head, in the recognition rate, size of images in the database and also the processing rate of the recognition.

3.2 Project Description

3.2.1 Objective

The objective of the project is to develop a system that recognizes the faces using thermal signatures of the person, because it has many advantages to the classic face recognition like light problems and head poses. Working on improving the recognition rate of the thermal image. Trying to have a bigger database to have more images to be compared with or improving the recognition processing. Then after coming up with the most accurate algorithms on the dataset, using these algorithms will be our objective in making an application that recognizes people's faces based on their thermal images to have the ability to grant access for them or not to universities control rooms.

3.2.2 Scope

Trying many algorithms for features extraction and classifying. Testing these algorithms and calculating the recognition rate, size of database and the processing rate of the captured images. Also trying hybrid systems to use more than one algorithm or combining them to have a better recognition rate and speed. Trying more than one database as well to calculate the best result. And if we failed in this, using thermal camera to capture the images will be the alternative method.

3.2.3 Project Overview

Many algorithms have been used before for this problem. We do not have specified algorithms to use for our proposed model, but there are a list of algorithms that we have in

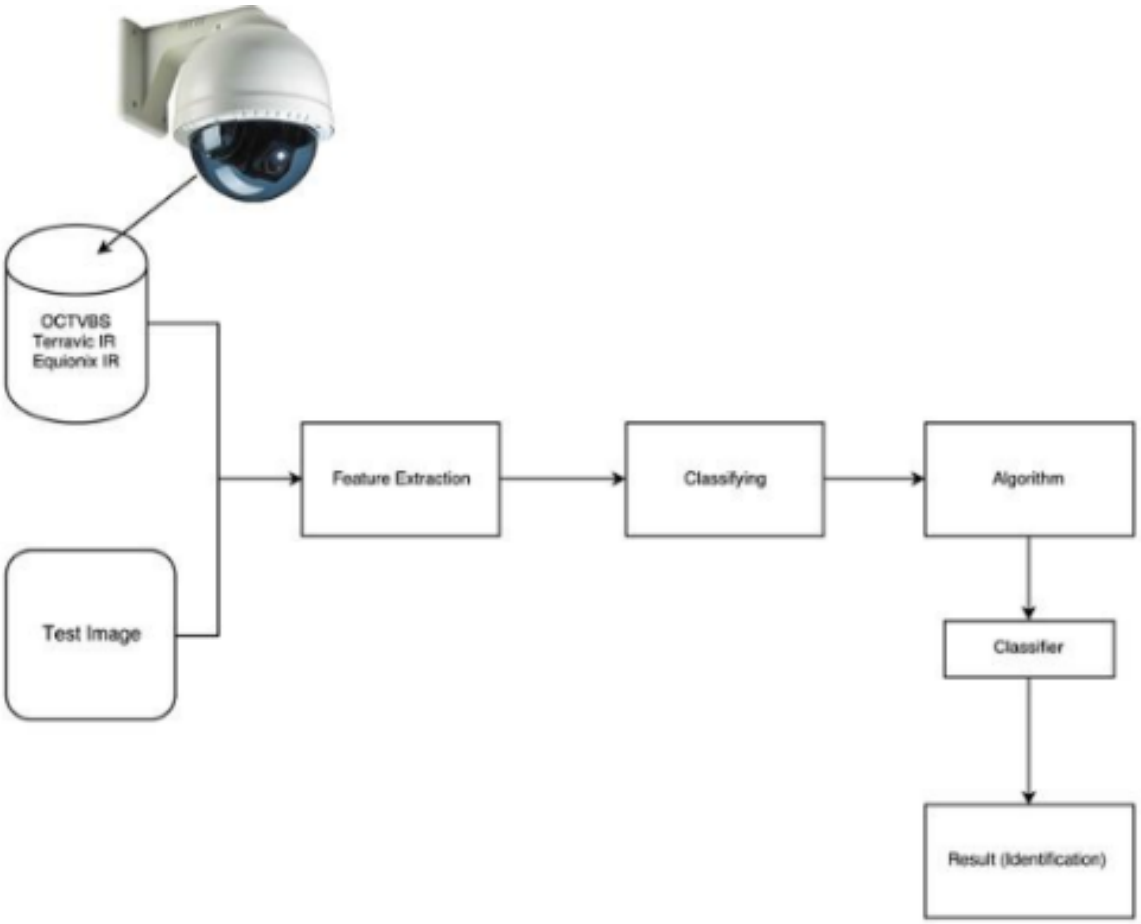


Figure 3.1: System Overview

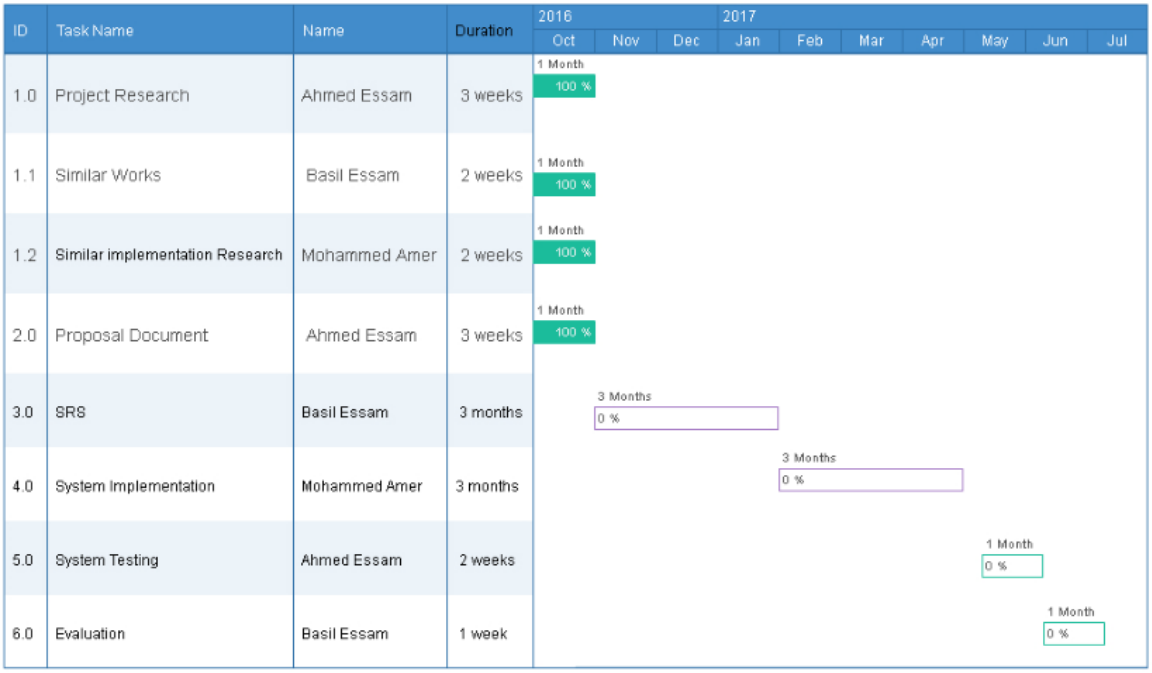
mind that we are going to test as mentioned in the scope. For example; (SFTA), (CNN), (ANN) for features extraction. (PCA), (LDA) for dimensionality reduction.

3.2.4 Comparison with Proposed Project

	Human Thermal Face Recognition Based on Random Linear Oracle(RLO) Ensembles[1]	**Thermal Human Face Recognition Based on Gappy-PCA[2]**	**Real Time Efficient Parallel Thermal Face Recognition[3]**	**FBA for Thermal & Visible Face Recognition under Pose and Expressivity Variation[4]**	**Our Proposed Method**
Algorithms	- (SFTA) Features extraction - (PCA,LDA) Dimensions reduction - (RLO) Recognize thermal image	- (PCA) - (GPCA) Store the statistical information that is missing in the PCA	Parallel Fusion (Gabor Filter)	- (PCA) - (KNN) Classifier	- Features Extraction: (SFTA, PCA, CNN, ...) - Dimensionality Reduction: (PCA, LDA, ...) - Classification: (RLO, KNN, CNN, ...)
Database	Trerravic Facial IR Database	Their Own Database(12 frontal 112*92 images)	Equinox Face Database	- OTCBVS benchmark - Notre IR Database - Equinox IR Database	(Terravic Facial IR DB, OCTBVS, Equinox IR DB, ...)
Best Recognition Rate	94.12%	98.61%	98.6%	1-NN : 90.84% 3-NN: 87.18% 5-NN: 81.76% 7-NN: 78.86%	–

Figure 3.2: Comparison Table

3.3 Project Management and Deliverables



ID	Task Name	Name	Duration
1.0	Project Research	Ahmed Essam	3 weeks
1.1	Similar Works	Basil Essam	2 weeks
1.2	Similar implementation Research	Mohammed Amer	2 weeks
2.0	Proposal Document	Ahmed Essam	3 weeks
3.0	SRS	Basil Essam	3 months
4.0	System Implementation	Mohammed Amer	3 months
5.0	System Testing	Ahmed Essam	2 weeks
6.0	Evaluation	Basil Essam	1 week

Figure 3.3: Tasks and time Plan Chart

3.3.1 Budget and Resource Costs

In case of buying a thermal camera, its cost is around 200USD-350USD.

3.3.2 Supportive Documents

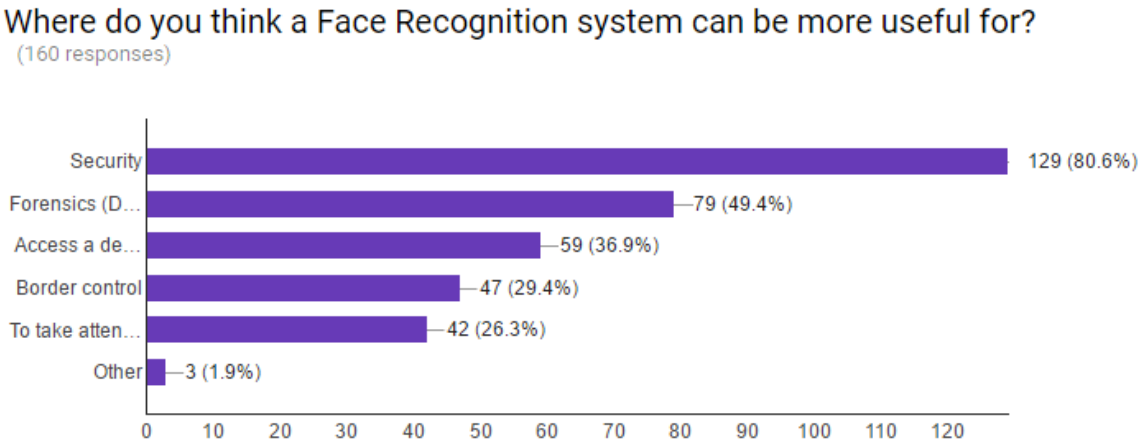


Figure 3.2: Survey Results showing the system's most useful fields

Chapter 4

Software Requirements Specifications Document

4.1 Introduction

4.1.1 Purpose of this document

The main purpose of this document is to make a clear and understandable document for the software designers to have them reached the idea of this project and be able implement its requirements and functions properly and in a right way.

4.1.2 Scope of this document

A- Project Objective: Develop a system that will be able to recognize human faces based on their thermal images after making a comparative study between the algorithms that have been used in related systems and testing them on our database to come up with the best algorithm that can be used in real-time and have the best accuracy.

B- Deliverables:

leftmargin=+.6in

- Developing an application that can be specialized in making universities control rooms more secured by having a thermal face recognition system that allows desired people to enter the rooms based on their authorities.

C- Milestones: leftmargin=+.6in

- Proposal Document – October 2016
- Software Specification Document – February 2017
- First Prototype – March 2017
- SDD - April 2017
- Integrated System – May 2017
- Final Thesis – June 2017

D- Technical Requirements: leftmargin=+.6in

- Start-up and processing in less than 10 secs
- Low memory consumption

E- Constraints: leftmargin=+.6in

- Thermal Camera isn't brought yet , due to its high cost
- Best Algorithm to be applied
- System isn't working in real time yet

4.1.3 Overview

The delivering product will be able to identify people's faces based on their thermal images. Thermal images had been proven to have a better identification accuracy than the classic or visible one, so a product that could be able to identify thermal images would be much better and more useful[6].

4.1.4 Business Context

Thermal face recognition can be used and implemented in many real world applications. Based on a survey that has been done, this project can be most usefully in identifying faces in security[3]. With the system's ability, the system that will be able to recognize faces based on their thermal images in universities' control rooms in order to be more secured by having a thermal face recognition system that allows desired people to enter the rooms based on their authorities.

4.2 General Description

4.2.1 Product Functions

The project works as follows; first, enrollment of the desired people that will be using the application has to be done; by saving their details, information and authorities. There are two different stages, training stage and testing stage. In training stage, the training process is applied on the thermal images, it detects the shown and available faces in the desired area, then applying segmentation on the images in order to help having a better accuracy and clearer images to work on. Features are being extracted from the images after applying the segmentation stage, these features are being extracted and stored in the database to be able to compare results with them in the testing stage. And finally, we classify the image based on its face in order to identify the face in the testing stage. In testing stage or real time stage, the system detects the acquired face in the area. Segmentation step is applied to work only on the desired area which is the face region. Then features are extracted from these images and comparing them with the stored ones to be able to classify the images from the previously tested ones. Then deciding whether to give the person the permission to access the rooms or not.

4.2.2 User Characteristics

Users of the system are preferably to have a general background about computers systems and technology overall, not so much of experts but have a good knowledge that will make them a able to understand how the system works and use it in their own domains and applications as the system does not have much interaction between the user and it but only in training the system to store new images and data. No specific age or gender is required as long as the user has enough knowledge and ability to use the system.

4.2.3 User Problem Statement

Visible or classic face recognition does not meet all the user's requirements of doing the job effectively as it has many backwards and problems such as head pose, position, facial expression and also the image has to be well lit [6]. Thermal face recognition was employed to solve these problems that faced the visible face recognition.

4.2.4 User Objectives

The user's main objective is to have a system that can work properly under the circumstances and problems that faced the visible faced recognition to be able to identify people's faces easily. Many applications the user can benefit from the system in them, mainly in security and forensics as has been mentioned before they were top priorities to people in the survey. But we are aiming to make an application for the universities' control rooms to improve its security.

4.2.5 General Constraints

1. Having a thermal camera that provides thermal images due to its high cost.
2. Deciding the best algorithm to be used after testing many.
3. Being able to work in real-time.

4.3 Functional Requirements

4.3.1 Admin login

Description: The admin will have a login credentials in order to have the ability to edit and updates the data of the users.

Input: Login credentials.

Output: Informs the admin whether he entered his credentials correctly or wrongly.

Action: The admin will login to the system if his credentials were right.

Criticality: This function is very important as the admin will not be able to make any modifications to the system if he does not login to it.

4.3.2 User Enrollment

Description: The admin will register the details and information of the desired people to be using the system.

Input: Captured images.

Output: Informs the user if the images are stored correctly.

Action: The user will be asked to enter the class or person's name of the captured image.

Criticality: This function is very important as the details and authorities of the users have to be stored.

4.3.3 Capturing training images

Description: The admin will capture images of the targeted people that the system will be working on.

Input: Captured images.

Output: Informs the user if the images are stored correctly.

Action: The user will be asked to enter the class or person's name of the captured image.

Criticality: This function is essential and very important in the process as it's a vital one in completing it.

4.3.4 Applying Segmentation to training Images

Description: The captured images of the users will go through the segmentation stage by segmenting the images to work on the face area only which can help in having better accuracy in the classification stage.

Input: Thermal images.

Output: Showing the segmented images.

Action: Segmentation stage will be applied to the images by focusing on the face area only and removing the environmental distractions.

Criticality: This function is important in the system as it will help in having better accuracy in the classification stage.

4.3.5 Applying Features extraction to training Images

Description: Every face has unique features that are different in many ways,these features need to be extracted and stored using many techniques and algorithms in order to make the classification stage much easier and more accurate.

Input: Segmented thermal images.

Output: A feature vector of the extracted features.

Action: Segmented Images will go through features extraction step in order to have a feature vector.

Criticality: This function is an essential one as we need the feature vector of the features from every image in order to apply the classification based on it.

4.3.6 Uploading testing thermal image

Description: After the training stage, the specified thermal image face will be uploaded to begin the testing stage.

Input: Thermal image face.

Output: The thermal image will be shown in a picture box in the system.

Action: The image will be segmented and shown the output image in the picture box.

Criticality: This step is important as the user has to have a testing image to begin the testing stage.

4.3.7 Applying Segmentation on testing images

Description: After uploading the thermal image, segmentation stage is applied to the image by applying threshold and restoring the original pixels.

Input: Thermal Face Image.

Output: Segmented Image.

Action: Threshold algorithm will be applied to the thermal image, the face area will be binarized and the corresponding pixel will be restored from the original image.

4.3.8 Applying the feature extraction stage on testing images

Description: In this step, the user will apply the feature extraction stage to the image after uploading the segmented one.

Input: Segmented image.

Output: The output image will be shown in a new picture box after applying feature extraction to it.

Action: Feature extraction stage will be applied to the segmented image and shown in a new picture box.

Criticality: This step is very essential in the identification process as the classification step will be applied based on it.

Dependencies: This step depends on the previous one as the feature extraction step will be applied on the segmented image.

4.3.9 Testing images classification

Description: In this step, the user selects to classify the specified image based on the trained images.

Input: The output image after the feature extraction step.

Output: Informing the user about the identity of the specified image.

Action: The image is classified after extracting the features from it and comparing them with the trained images to identify the thermal face in order to know whether to allow the acquired person the access to the rooms or not.

Criticality: This is the vital and final step of the process to identify the images, so it is a very essential one.

Dependency: The classification step is dependent on the segmentation and feature extraction step, so that the classification can work properly.

4.4 Interface Requirements

The interface of the system requires the presence of a camera frame for the admins in order to have the ability to add a new user that can have the access to the system. The admins should have access to enroll a new person or user in the system.

4.4.1 User Interfaces

Here in this section, the Graphical User Interface (GUI) will be discussed and shown through images and screen-shots of the system.

4.5 Other non-functional attributes

Specifies any other particular non-functional attributes required by the system. Examples are provided below.

4.5.1 Security

In the system you will need a username and an encrypted password to access the database or add a new trained images for a person.

4.5.2 Accuracy

our System Accuracy depend on the trained images as we need a well trained dataset so it can be easier to detect the person in front of the camera.

4.5.3 Performance

The System should classify whether the person in front of the camera have an access to enter the room or not in range of 5 to 8 seconds.

4.6 Preliminary Object-Oriented Domain Analysis

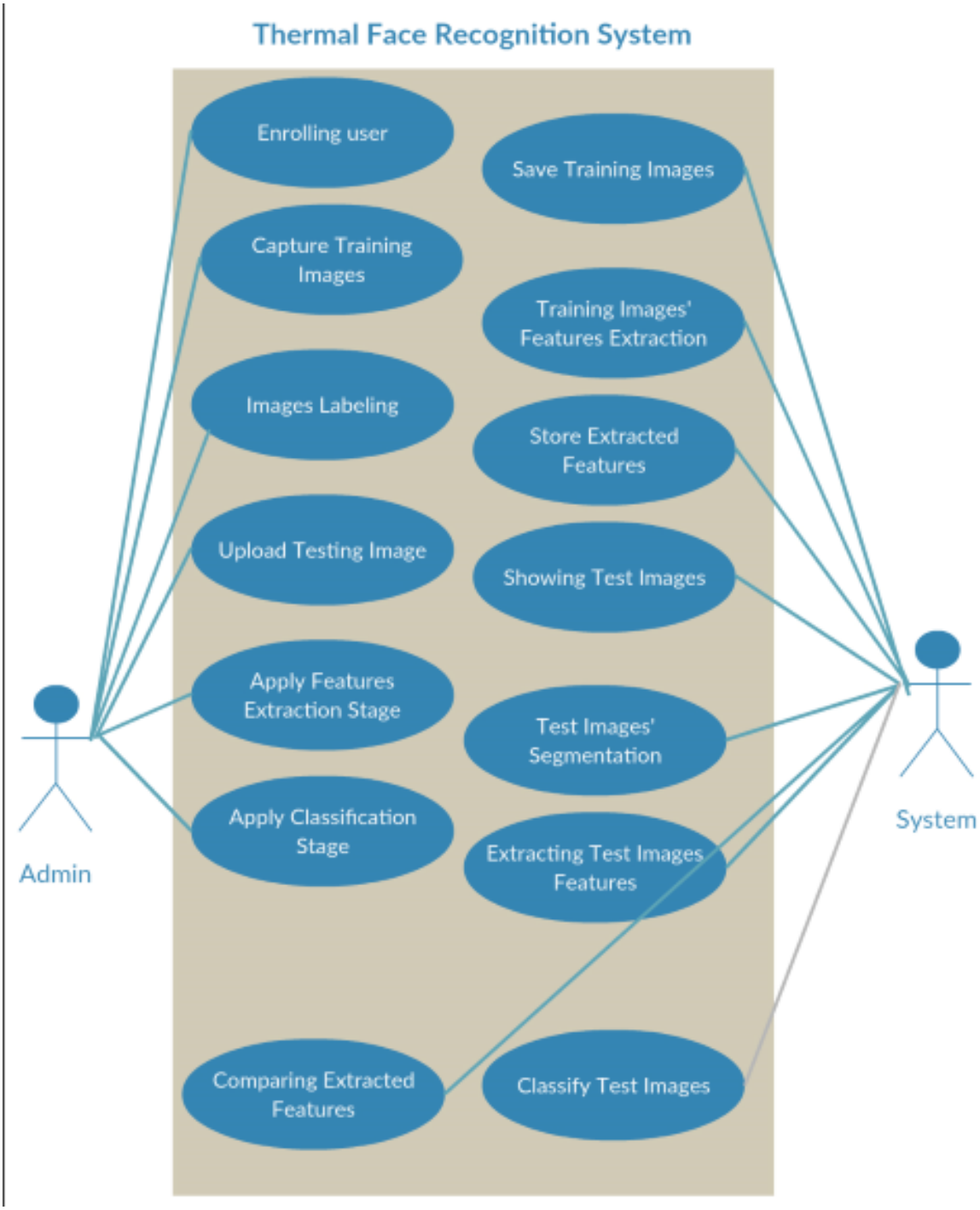


Figure 4.1: Use Case Diagram

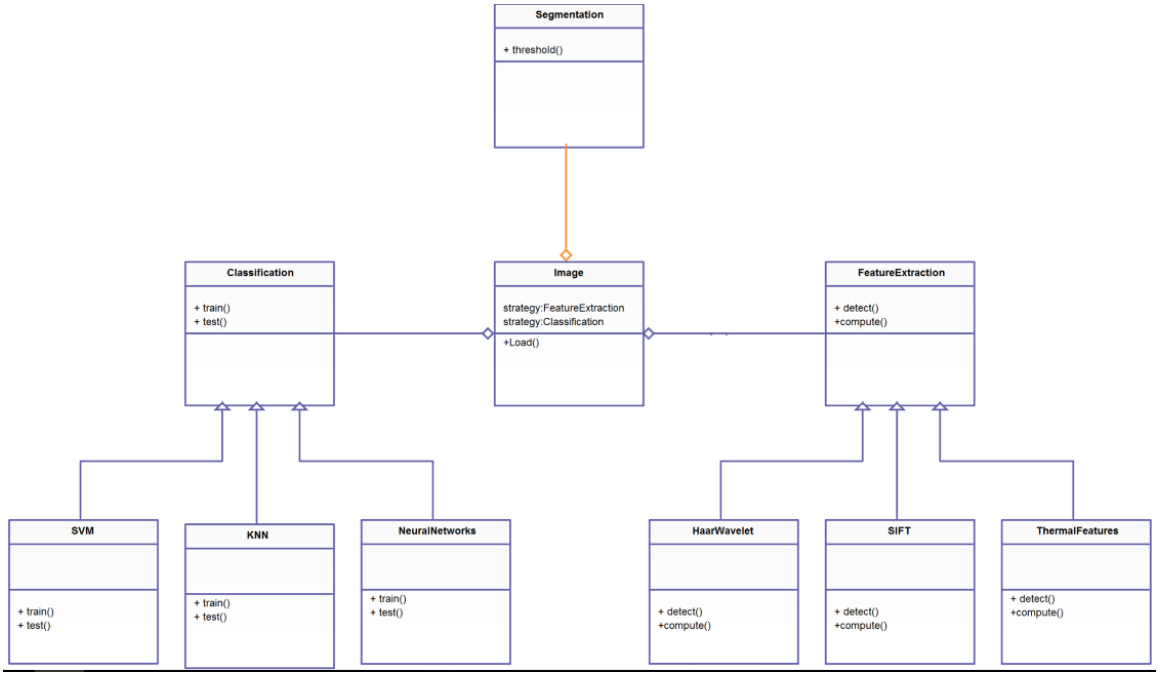


Figure 4.2: Primitive Class Diagram

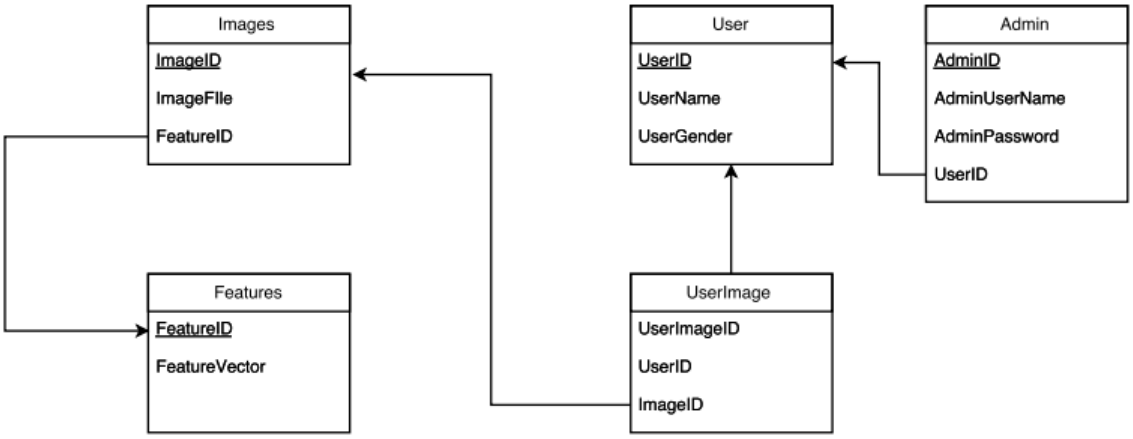


Figure 4.3: Database Tables Diagram

4.7 Operational Scenarios

The targeted users information that will be using the application has to be registered and stored in the systems database in order to have clear detailed data about them. Images of the targeted users have to be captured to be processed and trained later on in the identification process.The captured images of the users will go through the segmentation stage by segmenting the images to work on the face area only which can help in having better accuracy in the classification stage. Every face has unique features that are different in many ways, these features need to be extracted and stored using many techniques and algorithms in order to make the classification stage much easier and more accurate. In real time, the system has to detect the face area of the targeted users that will be using the system in order to start applying the identification stage. After detecting the face, segmentation of the face region will be applied in order to apply the process on the face area only and remove the environmental distractions.Extracting the Features of the face area is the most vital and important step in the process as they need to be extracted from the targeted users faces in order to use it later on in the classification stage.After extracting the features from the face, these features will be compared with the already stored ones in the database to reveal this persons identity to decide whether this person has the authority to enter the room or not. Taking action based on the persons identity whether allowing him to enter the rooms after identifying his face and revealing his authorities, or not giving and allowing him the access to these rooms.

4.8 Preliminary Schedule Adjusted

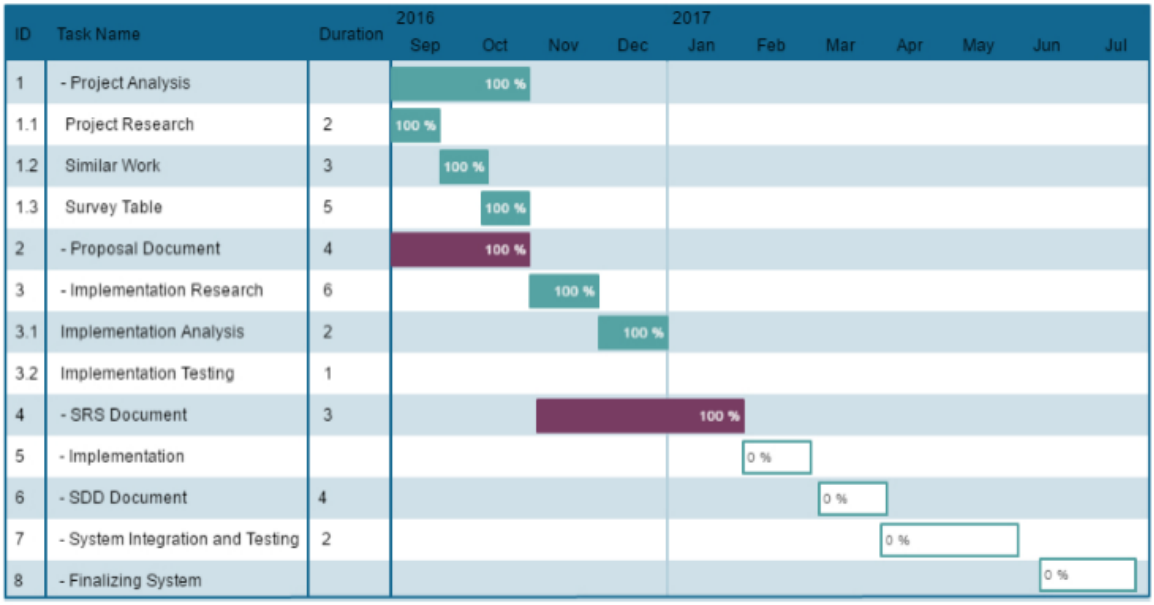


Figure 4.4: Tasks Plan Chart

4.8.1 Definitions, Acronyms, Abbreviations

1)FLIR: It is an abbreviation to Forward Looking Infrared Radiometer, it is the world leader in the design, manufacture, and marketing of thermal imaging infrared cameras.

4.8.2 Collected material

Thermal Face Images databases were available online, they contain static thermal face images to be used and tested [19],[2].

Chapter 5

Software Design Document

5.1 Introduction

5.1.1 Purpose

This software design document describes the architecture and system design of thermal face recognition system and how it will be developed based on its functionalities, use cased and architecture diagram.

5.1.2 Scope

Develop a system that will be able to recognize human faces based on their thermal images after making a comparative study between the algorithms that have been used in related systems and testing them on our database to come up with the best algorithm to be used. The application can be specialized in making universities control rooms more secured by having a thermal face recognition system that allows desired people to enter the rooms based on their authorities.

5.1.3 Overview

The document is composed of sections describing the software design components that are needed in order to implement this system, these sections are;

A. Purpose of the document: This section describes the purpose of this software design document and how it will be developed.

B. Scope of the project: This section describes the scope of the system and to what extendibles will it be able to work properly.

C. System Overview: This section describes the system's overview and how it is going to work based on its components and its materials.

D. System Architecture: This section describes the architecture design of this project that explains the relationships between the modules to achieve the complete functionality of the system.

E. Data Design: This section describes the database design of the system and how they are connected and related to each others.

F. Component Design: This section describes each component and how it works giving a summary of the algorithms used with graphs and pseudo-codes.

G. Human Interface Design: This section describes the interface design of the system that the user is going to be interacting with in order to deal with the system giving images of it.

H. Requirements Matrix: This section provides a reference that traces the components and structure to the requirements in SRS document.

5.2 System Architecture

5.2.1 Architectural Design

The system's architecture diagram used layered approach as each layer works based on the provided services it receives from the layer before it. Data layer is the lowest layer of an application. It is responsible of communicating with the used data storage like the thermal images, extracted features and the details of the users. Business layer includes the core business functionality of the application, which includes two components; the user enrollment stage, in which the admin/s of the system fill/s the user details, authorities and capture/s training images if the desired users in order to use it later on. The other stage is the system processing stage or the real application stage, in which the images pass by three main steps; image segmentation, features extraction and classification. Presentation layer contains components for users to interact with the application. It is responsible of processing user's input and returning the correct response back to the user which can be the user enrollment form that the admin/s fill or the form where they can login to the system.

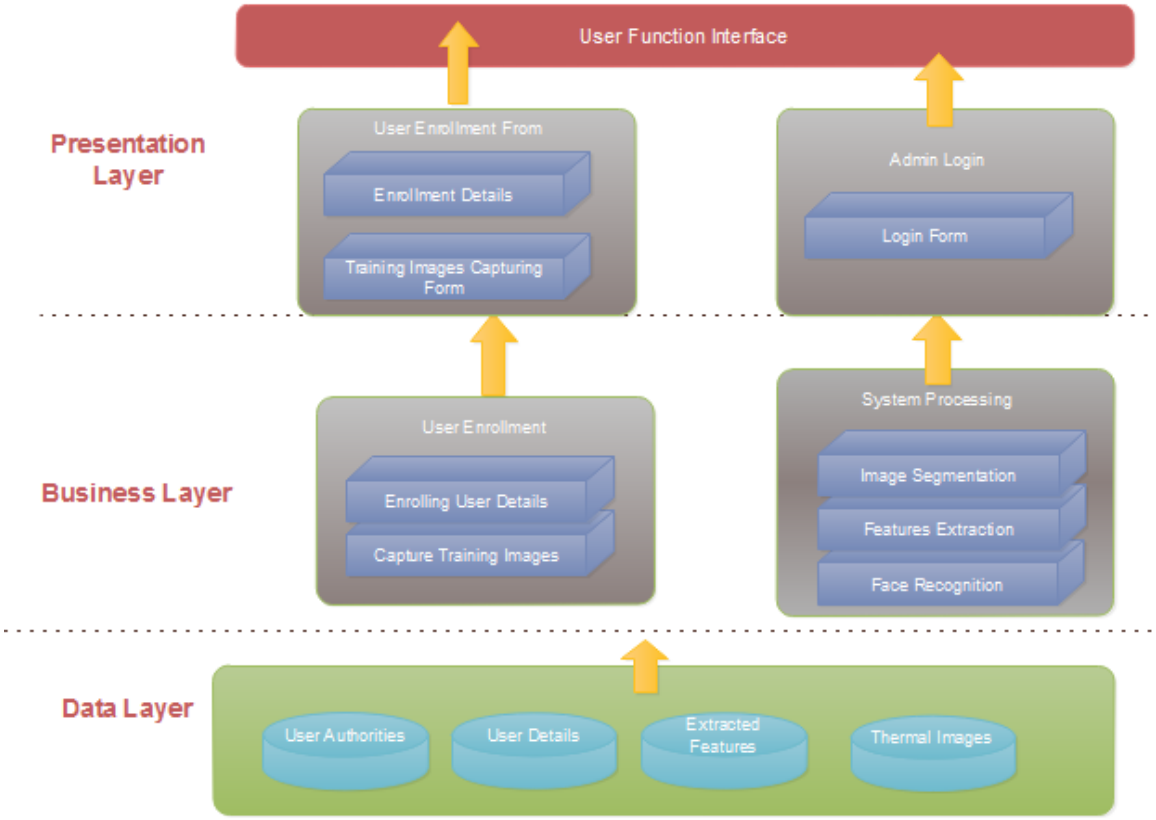


Figure 5.0: Architecture Diagram

5.2.2 Decomposition Description

5.2.2.1 Admin Login

First sequence diagram begins as the admin enters his credentials to be checked by the system.

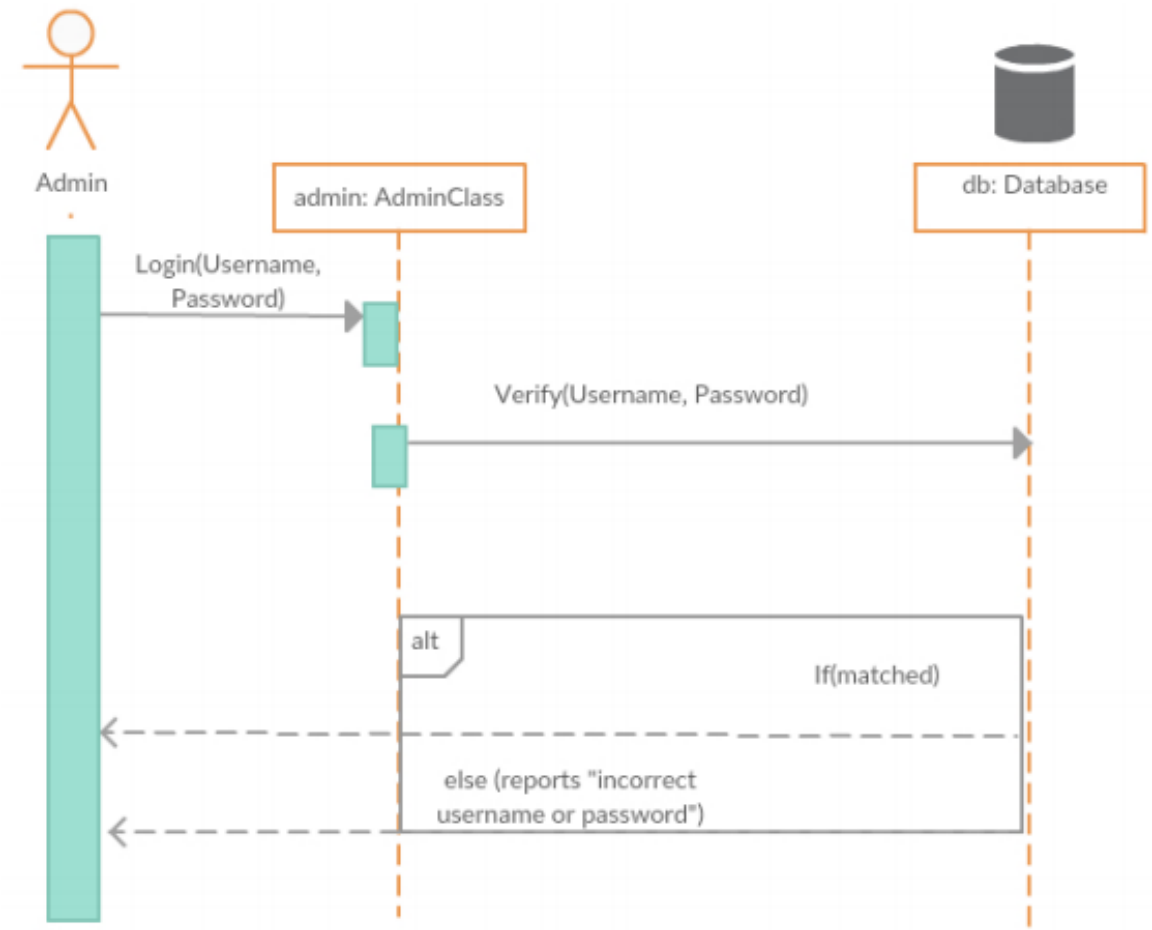


Figure 5.1: Admin Login Sequence Diagram

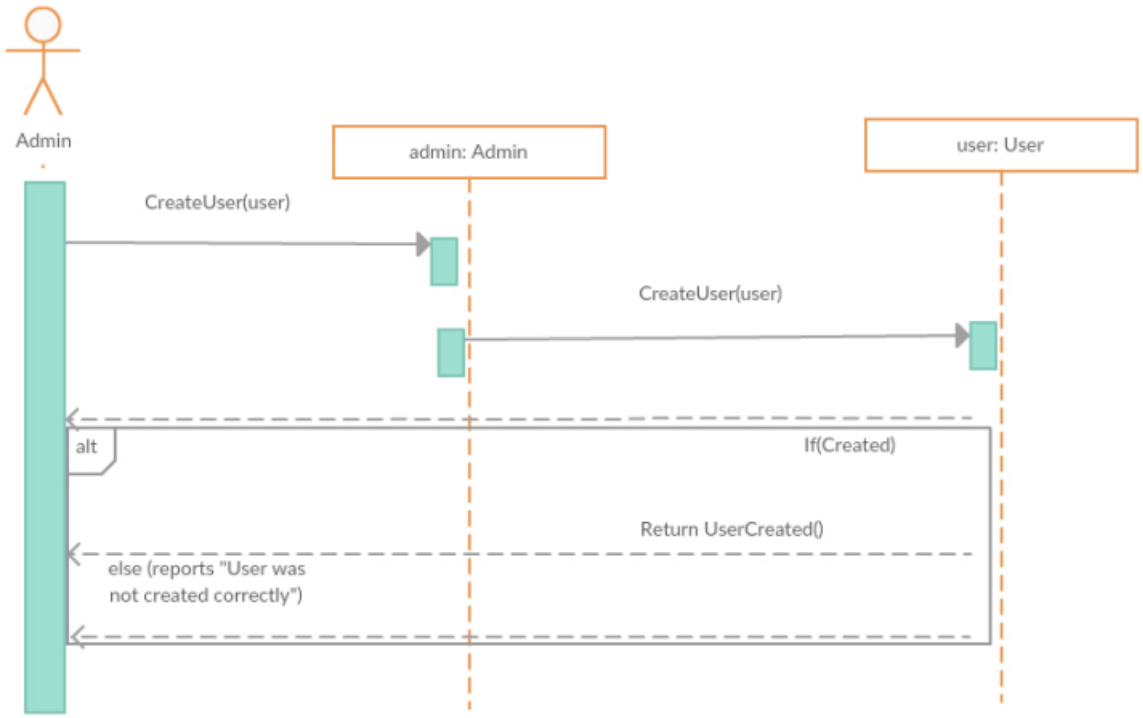


Figure 5.1: User Enrollment Sequence Diagram

5.2.2.2 Enrolling user details

This sequence diagram describes the sequence as the admin starts enrolling the user details into the system. First the admin creates an object from the user class.

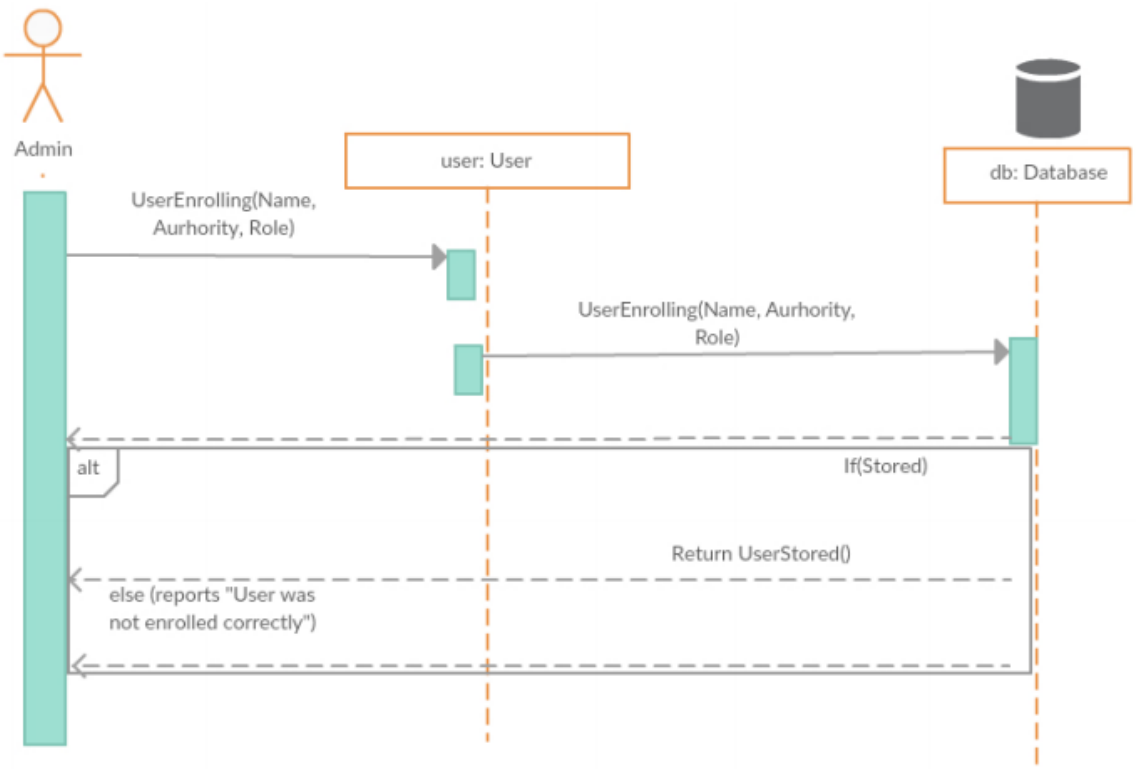


Figure 5.2: Storing User's details Sequence Diagram

Then the admin fills the user's details to be stored to his profile in the database.

5.2.2.3 Capturing training images

This sequence diagram describes as the admin stores the captured images of the users in the database.

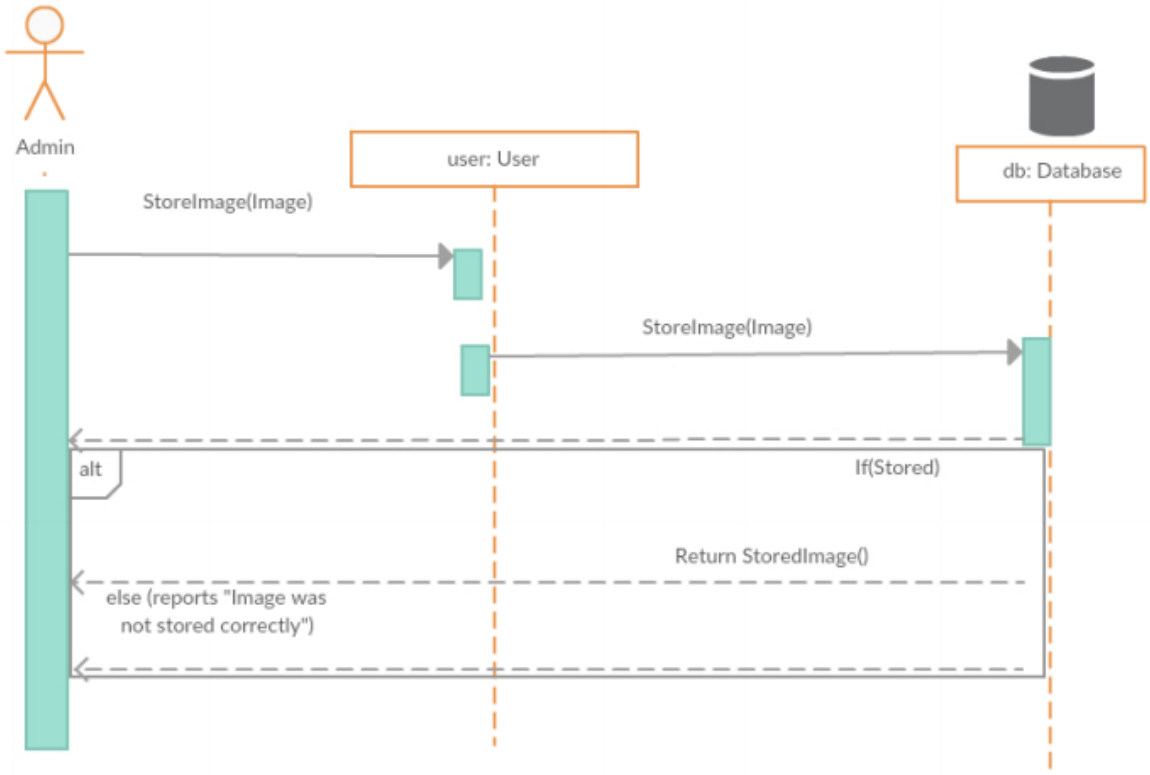


Figure 5.3: Capturing Training Images Sequence Diagram

5.2.2.4 Segmentation in the training stage

In this sequence diagram, the admin chooses to segment the training images after capturing it.

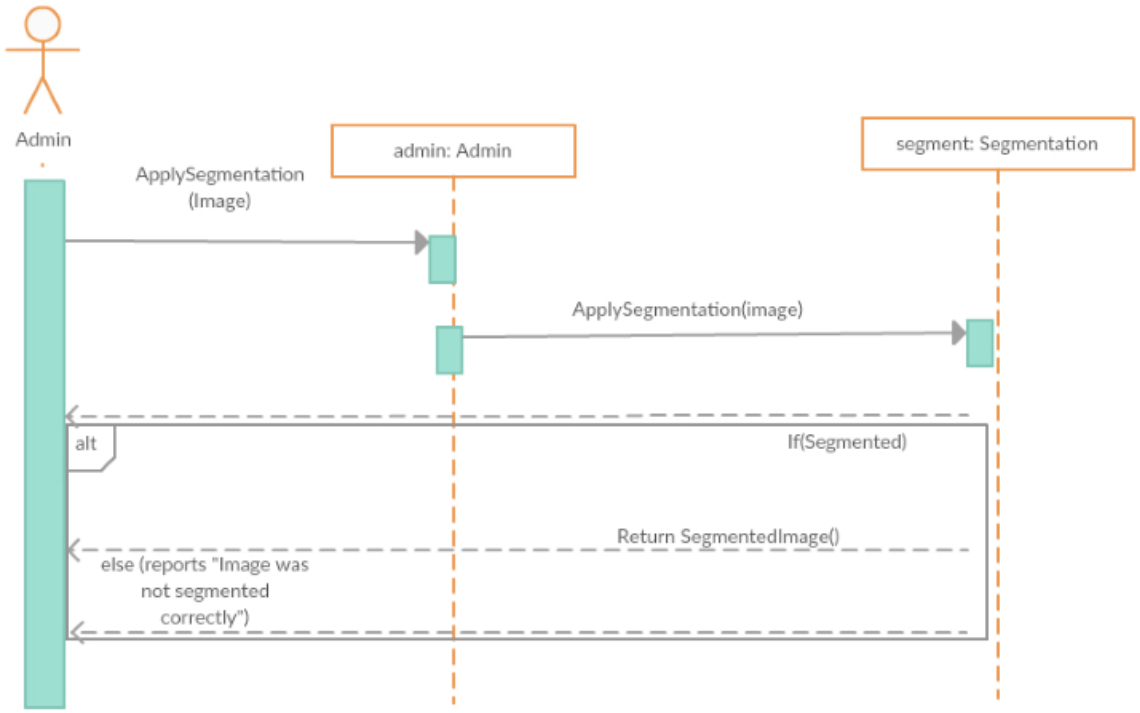


Figure 5.3: Training Images Segmentation Sequence Diagram

5.2.2.5 Features extraction in the training stage

In this sequence diagram, the admin chooses to extract features from the segmented images.

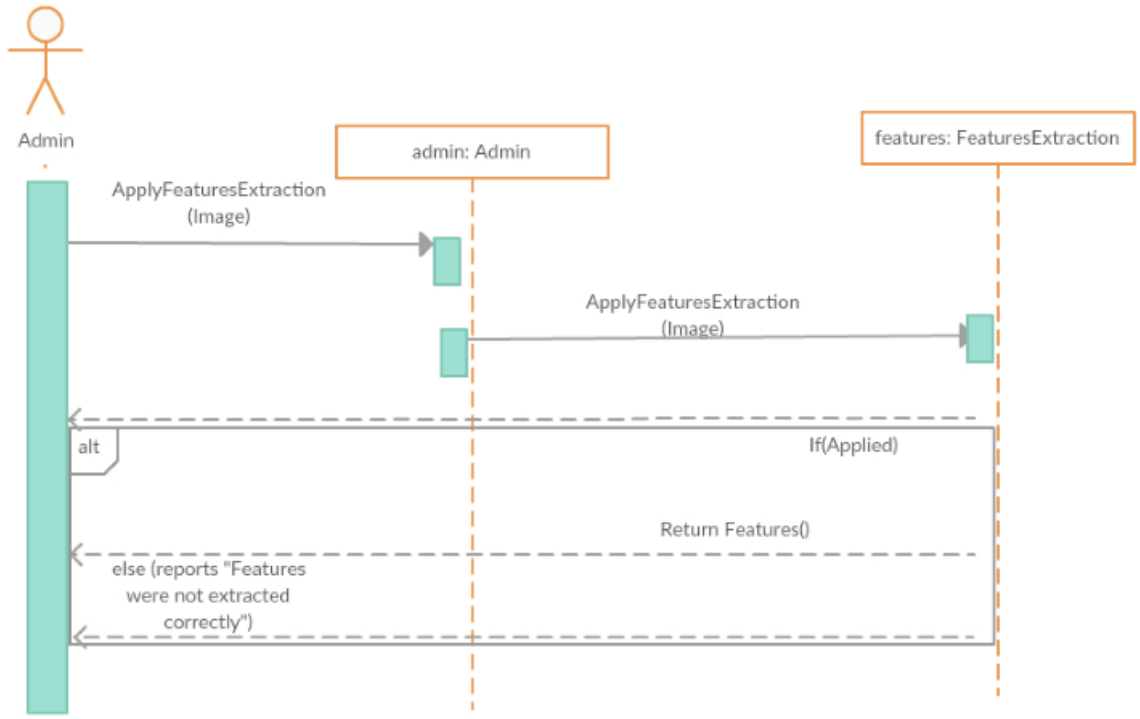


Figure 5.4: Training Images Features Extraction Sequence Diagram

Then in this sequence, the admin stores the extracted features in the database.

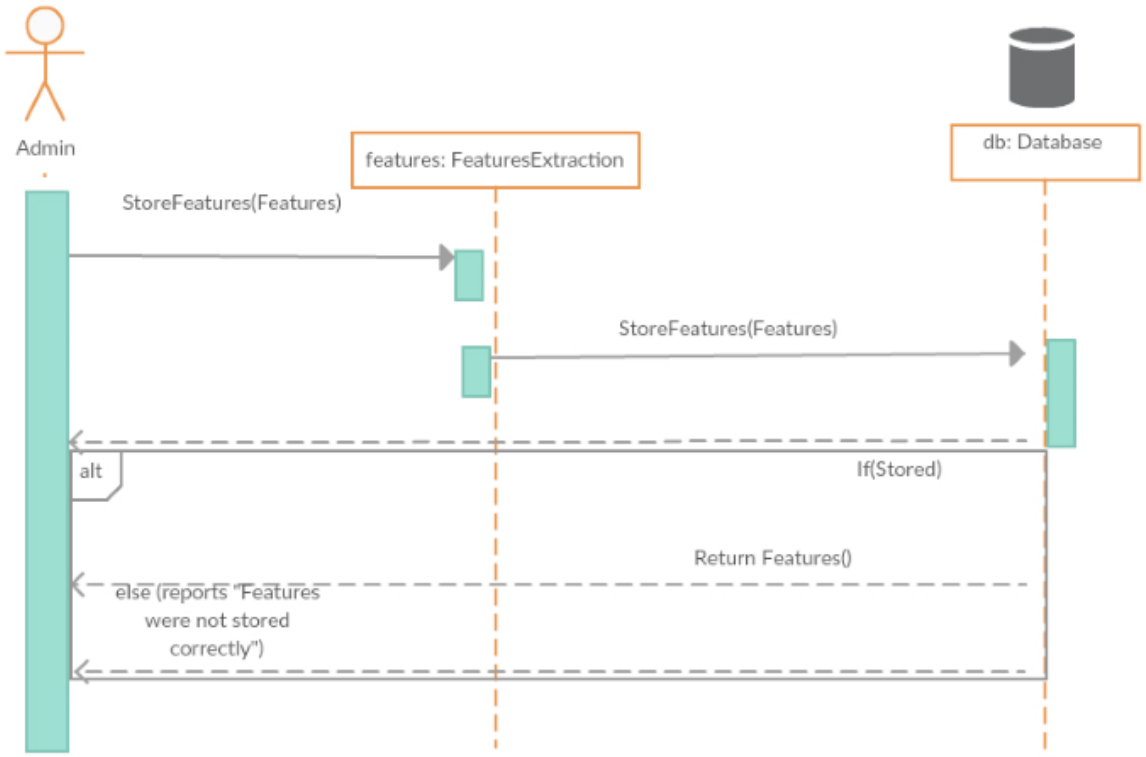


Figure 5.5: Storing Training Images Features Sequence Diagram

5.2.2.6 Face detecting in testing stage

This sequence diagram shows when the system detects a face in order to begin the recognition process.

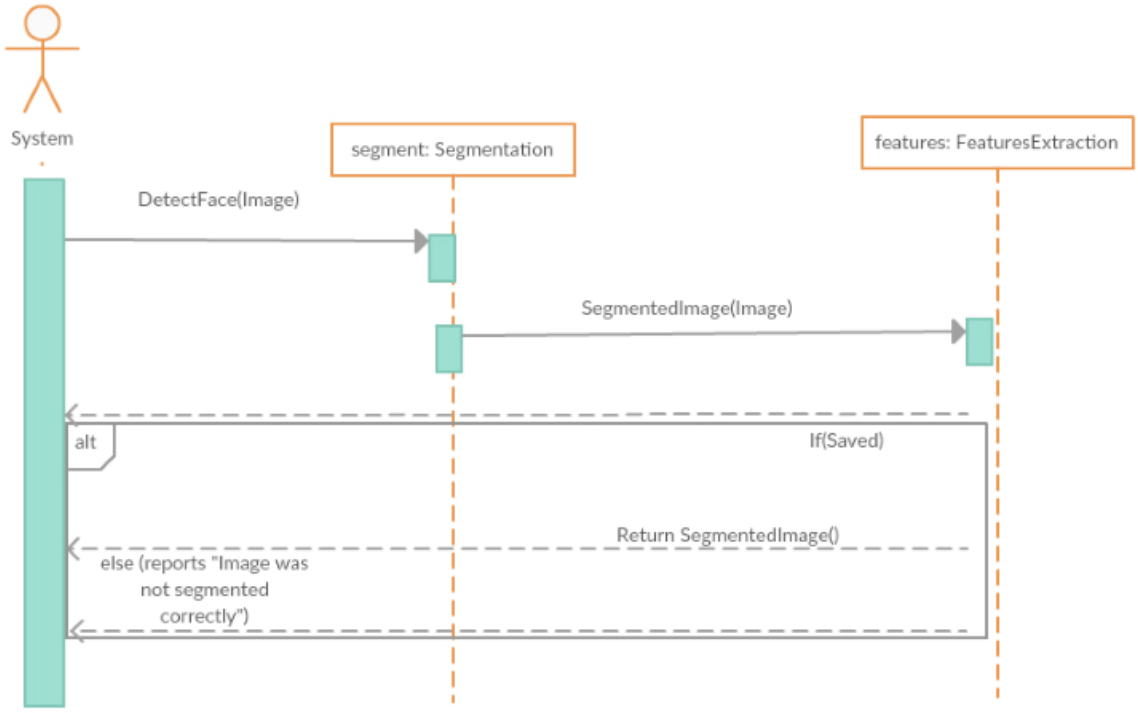


Figure 5.7: Face Detecting Sequence Diagram

5.2.2.7 Image segmentation in the testing stage

In this sequence, the system begins the segmentation stage after detecting the face area.

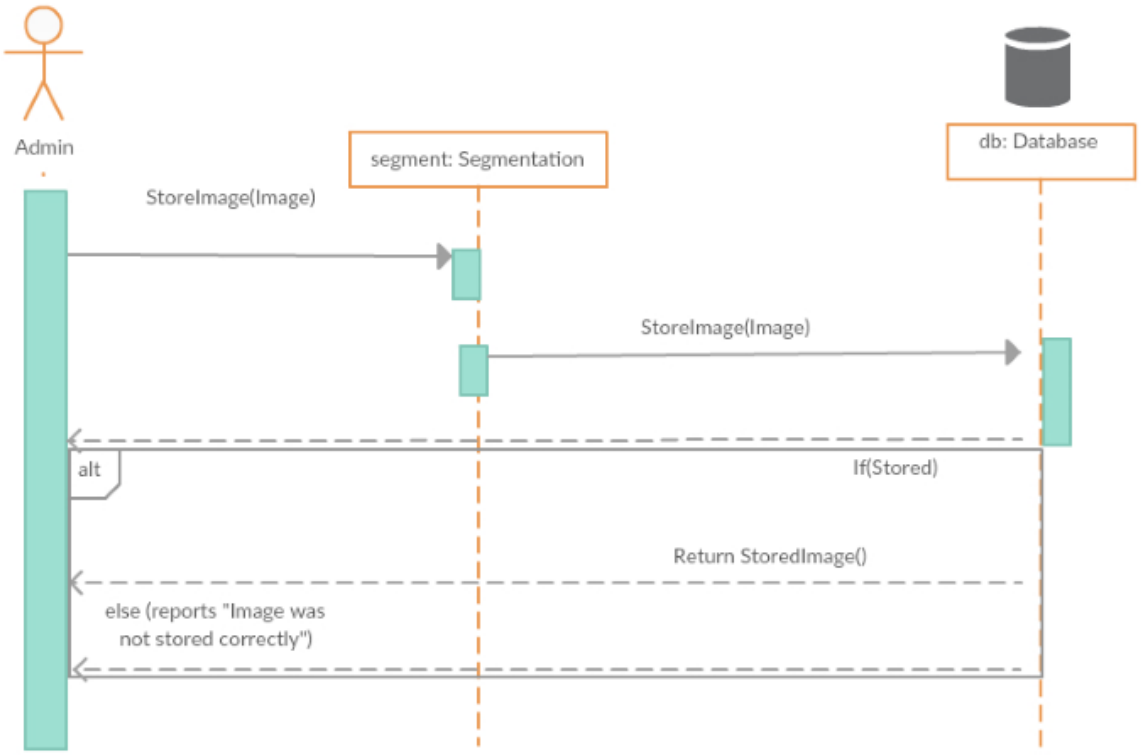


Figure 5.5: Testing Images Segmentation Sequence Diagram

5.2.2.8 Features Extraction in the testing stage

This sequence diagram shows the sequence when the system extracts features from the segmented face.

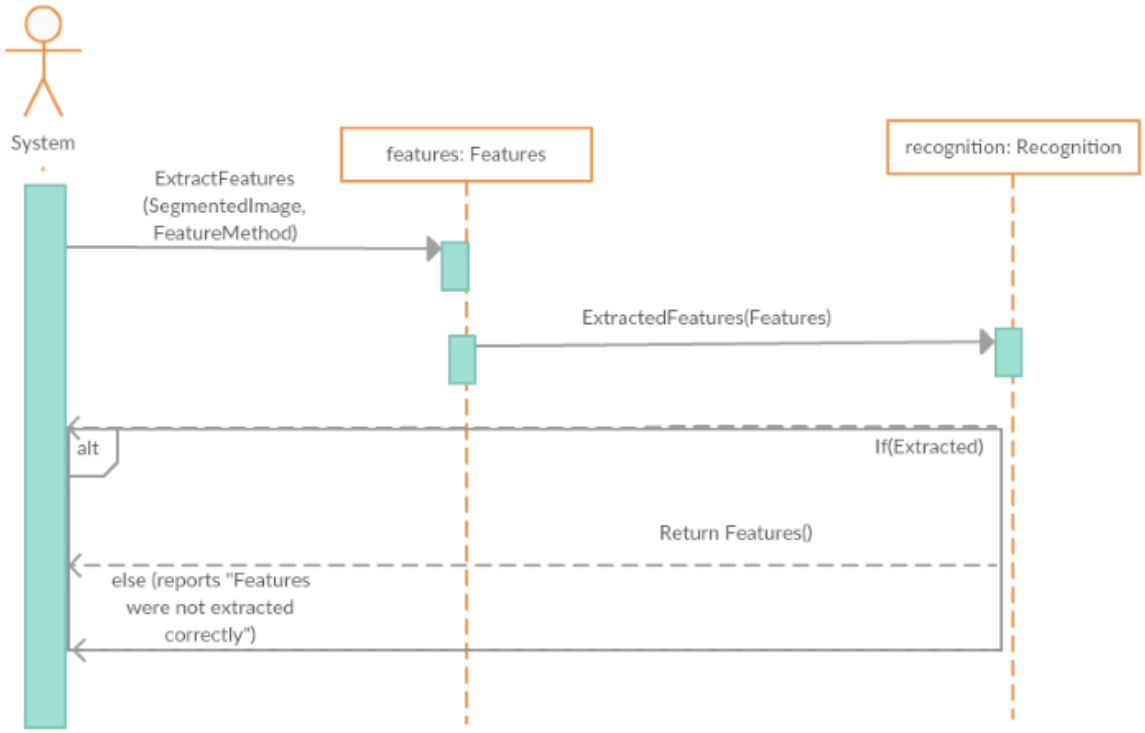


Figure 5.4: Testing Images Features Extraction Sequence Diagram

5.2.2.9 Face Recognition in the testing stage

This sequence diagram shows when the system tries to recognize the face after comparing the extracted features with the already stored ones.

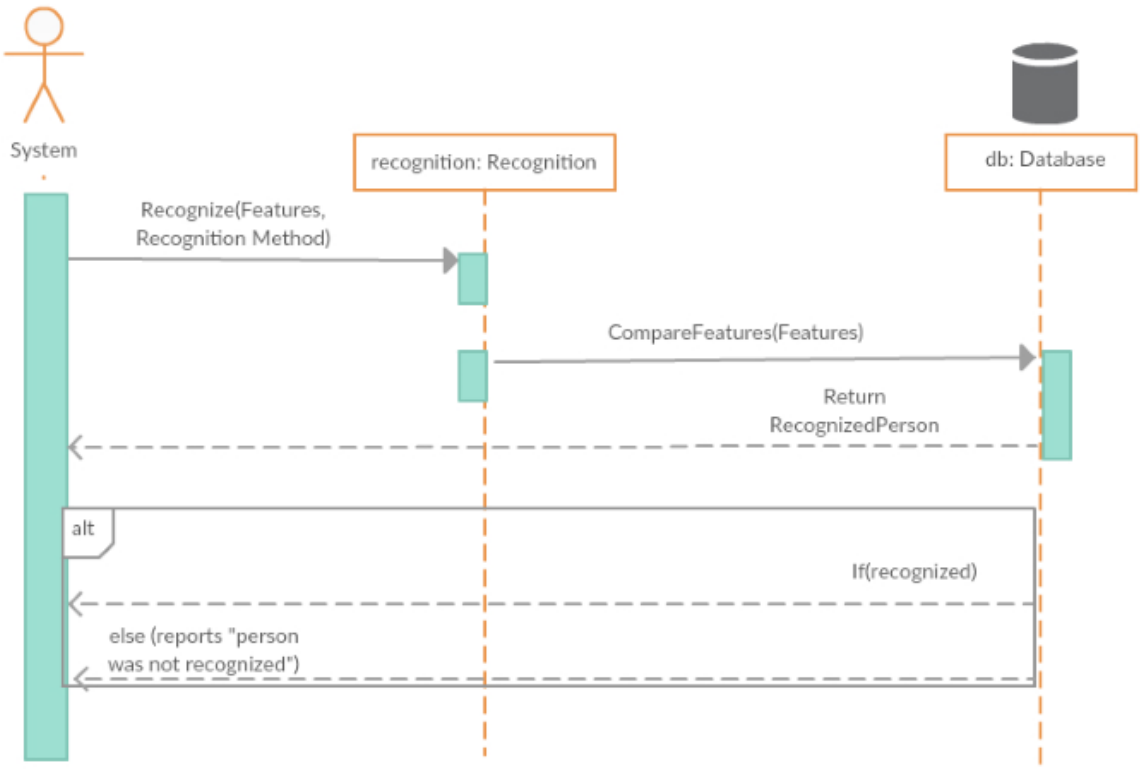


Figure 5.7: Face Recognition Sequence Diagram

5.2.3 Design Rationale

Using design patterns in constructing the structure of the system makes communication between designers more efficient. It provides a way to solve issues based on software development and also makes the overall system easier to understand and maintain. Using strategy design patterns specifically was a decision based on the runtime of the system, it enables an algorithm behavior to be selected at one time, and that is exactly what we are trying to achieve, using different features extraction algorithms and classification algorithms in order to have a comparative study between these various algorithms in order to come up with the best combination between them to use it later on.

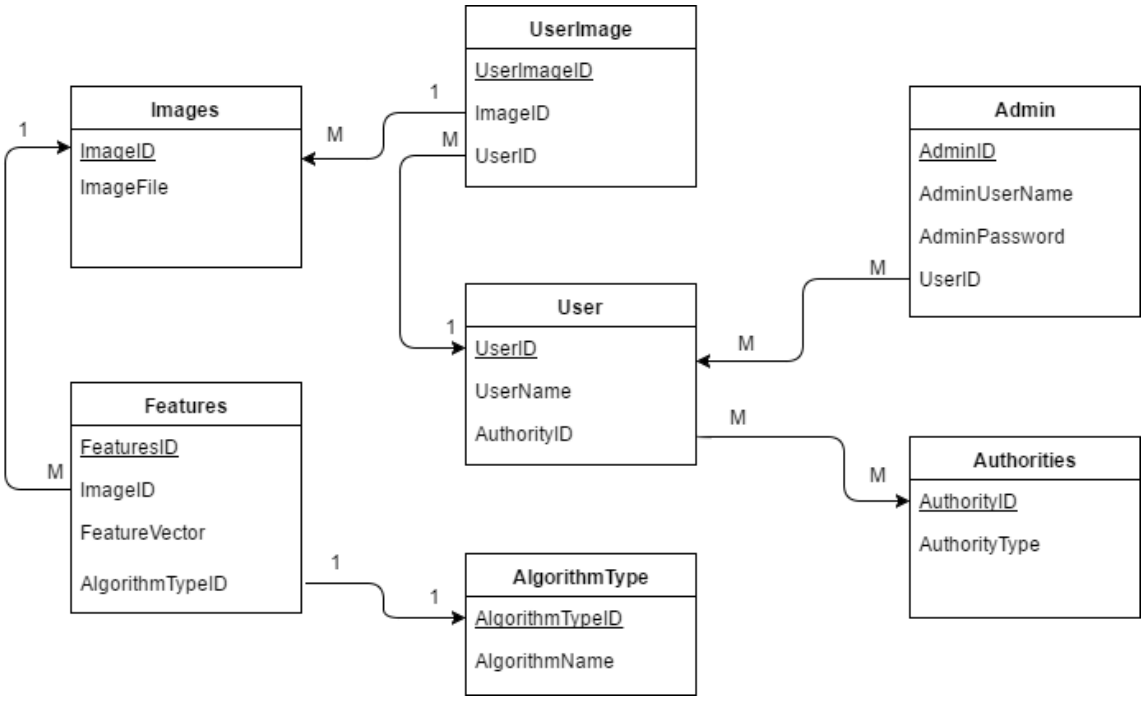


Figure 5.8: Database Tables of the system

5.3 Data Design

The system's database is composed of seven tables which we believe will be enough to achieve the system's requirements and benefits. We have an Admin class, which will be responsible for the system's management and it has an object of the User class. The User class has an object from the Authority class, in order to check it later on in the recognition stage. The UserImage contains an object from the User class and the Images class, it contains the user's details and his images. Features table has an object from the Images class to be stored by its features and also has an object from AlgorithmType table to determines which algorithm are we using in extracting the features.

5.3.1 Data Dictionary

Class Name	Function	Type
Images	Images()	void
	setImage()	void

Figure 5.8: Images Class

Class Name	Function	Type
Admin	Admin()	void
	setUserName()	void
	setPassword()	void

Figure 5.9: Admin Class

Class Name	Function	Type
Authority	SetAuthority()	void
	GetAuthotiy()	string

Figure 5.3: Authority Class

Class Name	Function	Type
SIFT	ExtractFeatures()	float
	Compute()	mat
	Detect()	mat

Figure 5.5: SIFT Class

Class Name	Function	Type
HOG	ExtractFeatures()	float
	Compute()	mat
	Detect()	mat

Figure 5.6: HOG Class

Class Name	Function	Type
SVM	SetType()	void
	SVMTrain()	void
	SetKernel()	void
	Predict()	float

Figure 5.7: SVM Class

Class Name	Function	Type
NeuralNetworks	SetLayerSize()	void
	SetNumberNeurons()	void
	SetActivationFunction()	void
	Train()	void

Figure 5.8: Neural Networks Class

5.4 Component Design

A. Class Diagram

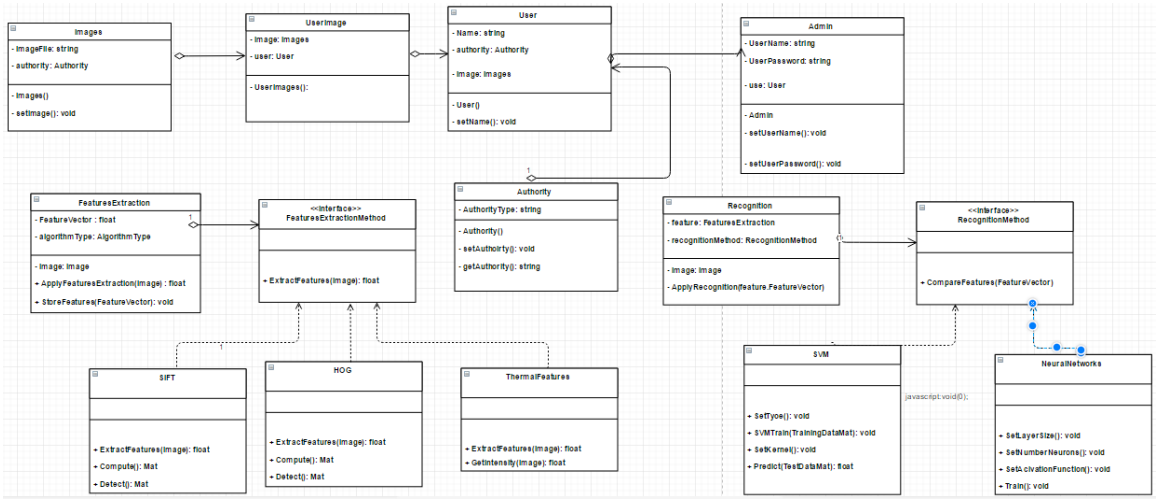


Figure 5.9: System's Class Diagram

5.5 Humnan Interface Design

5.5.1 Overview of User Interface

The user interface of the system is composed of two main stages; training stage and testing stage. In training stage, the admin has the ability to login into the systems by entering his credentials. Then, the admin will have the ability to enroll a new user into the system by filling his details, capturing training images of him and enrolling their authorities. The admin will have the ability to segment, extract features from the training images and saving the images into the database.

5.5.2 Screen Images

Here are Screen Shoots for our application. The admin will be asked to enter his credentials in order to login so he can add a new profile.

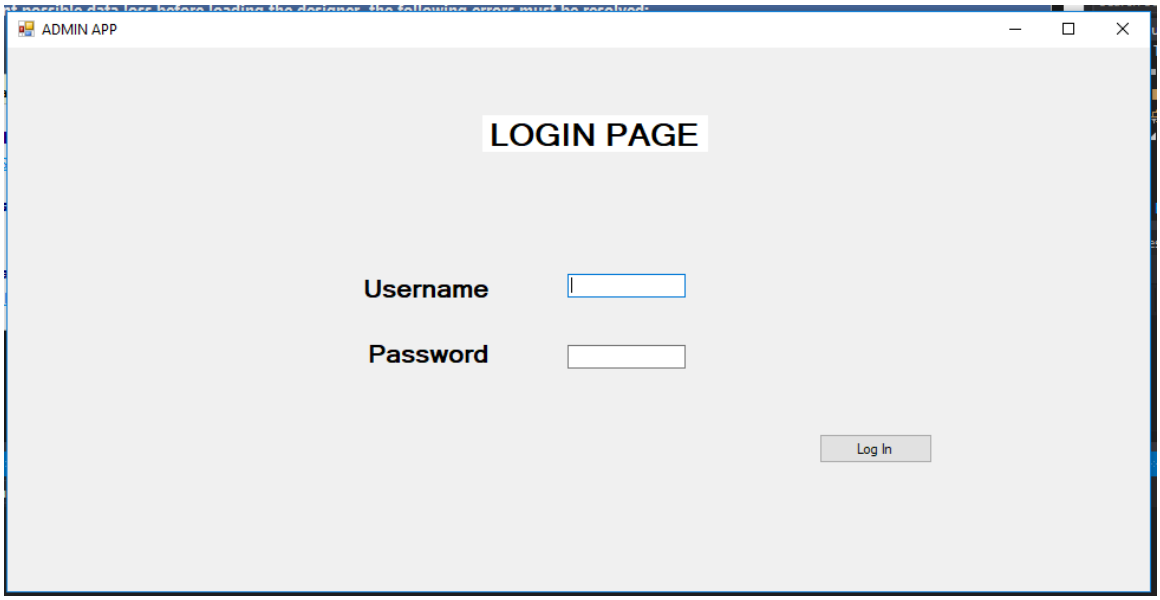


Figure 5.11: Admin Login Screen

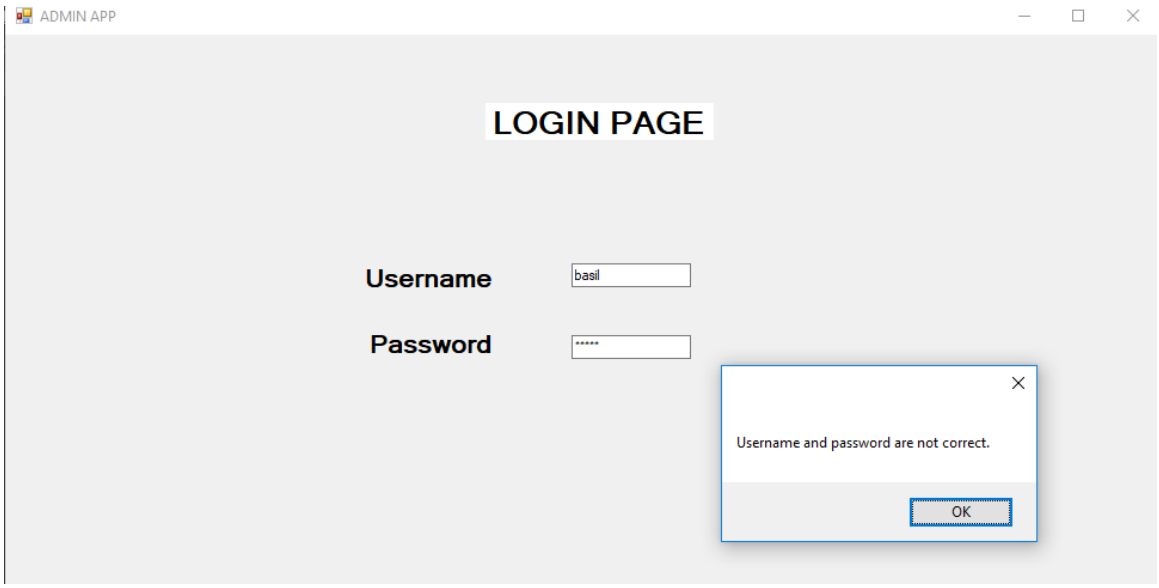


Figure 5.12: Error message on entering wrong credentials

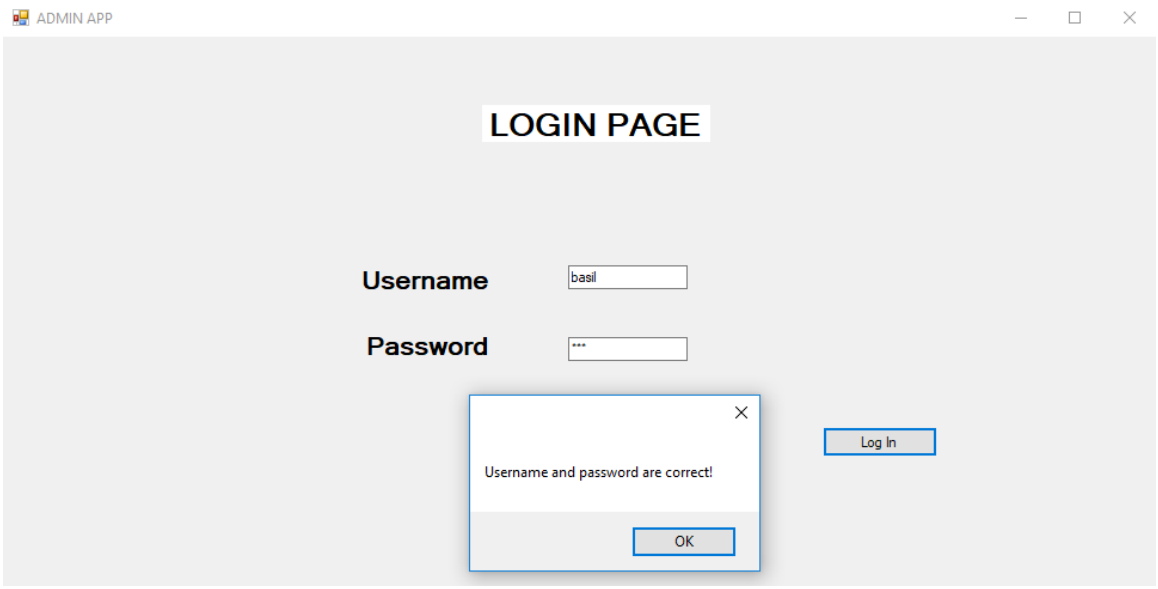


Figure 5.13: Indicating message that login was successful

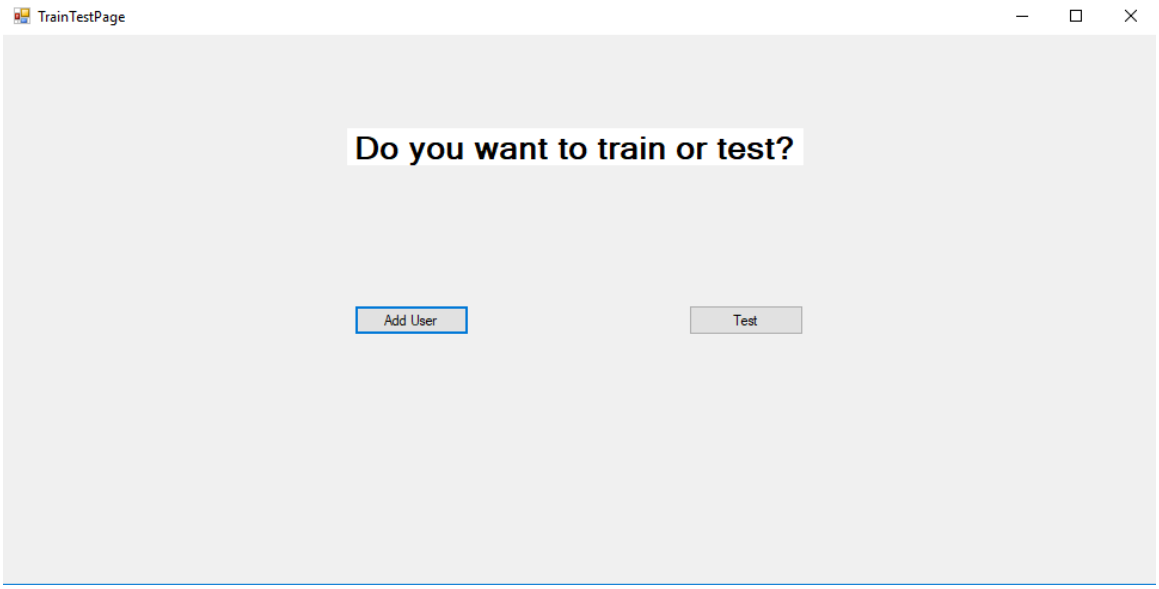


Figure 5.14: Home screen asking the admin whether he wants to train or test

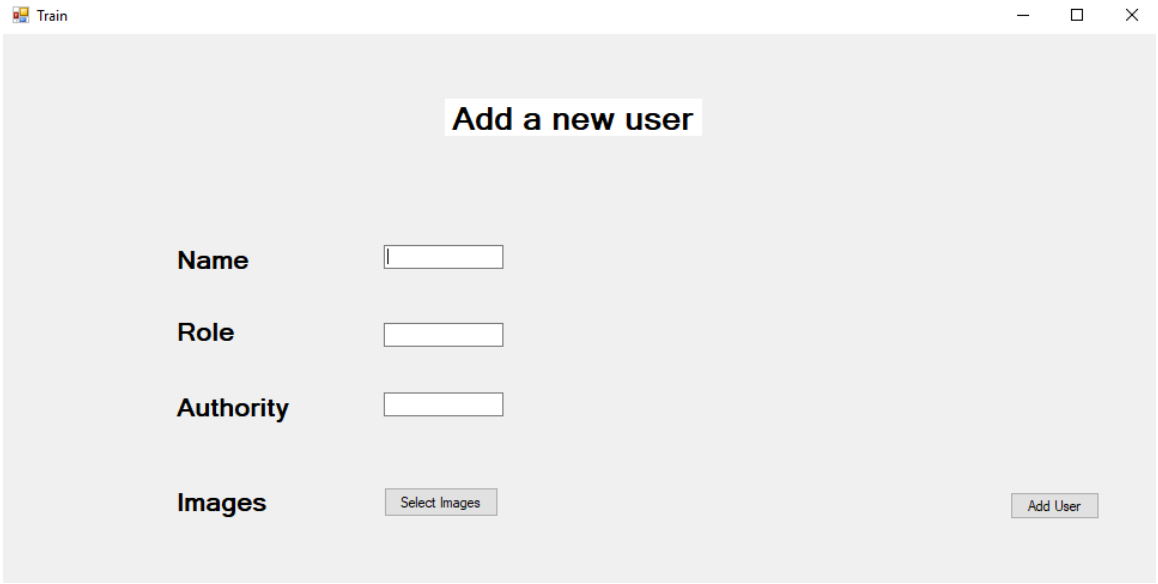


Figure 5.15: Adding user screen

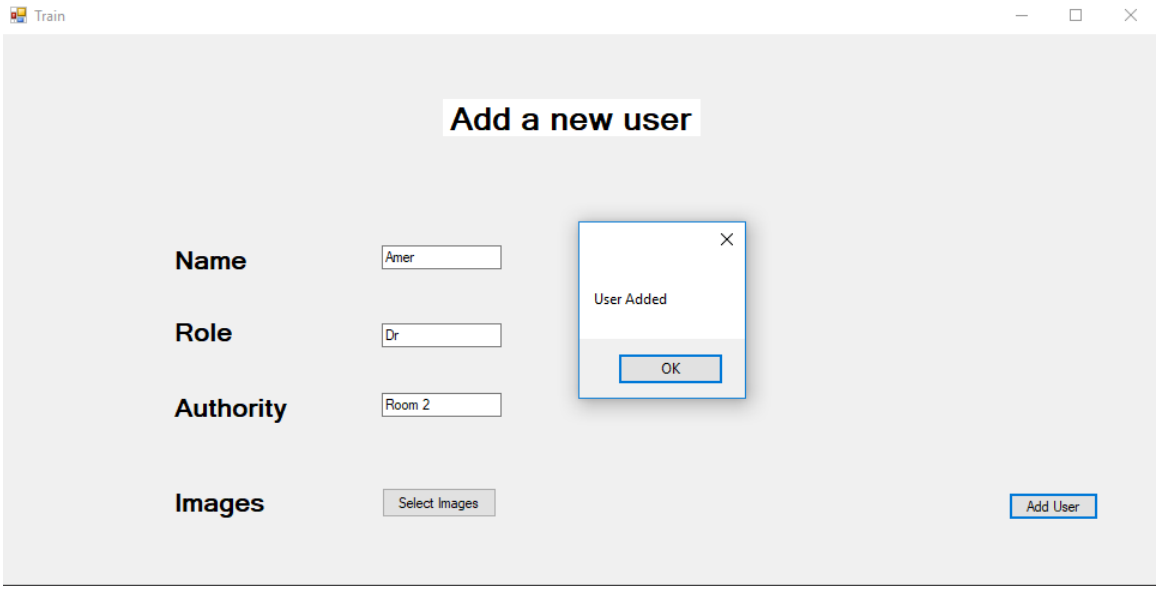


Figure 5.16: Informing Message that the user has been added

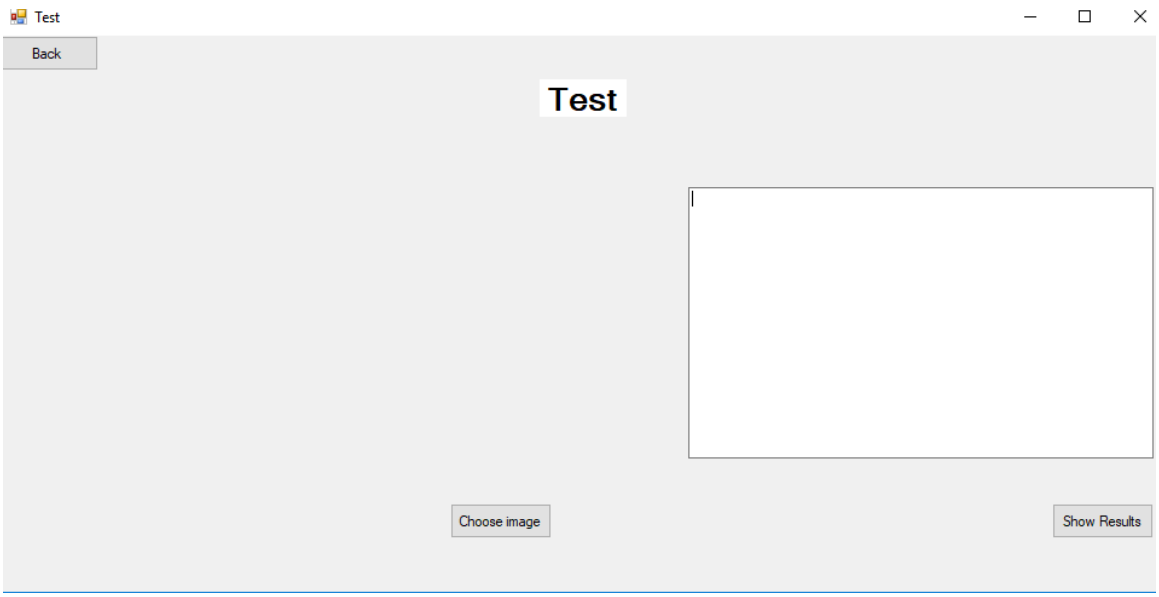


Figure 5.17: Test page screen

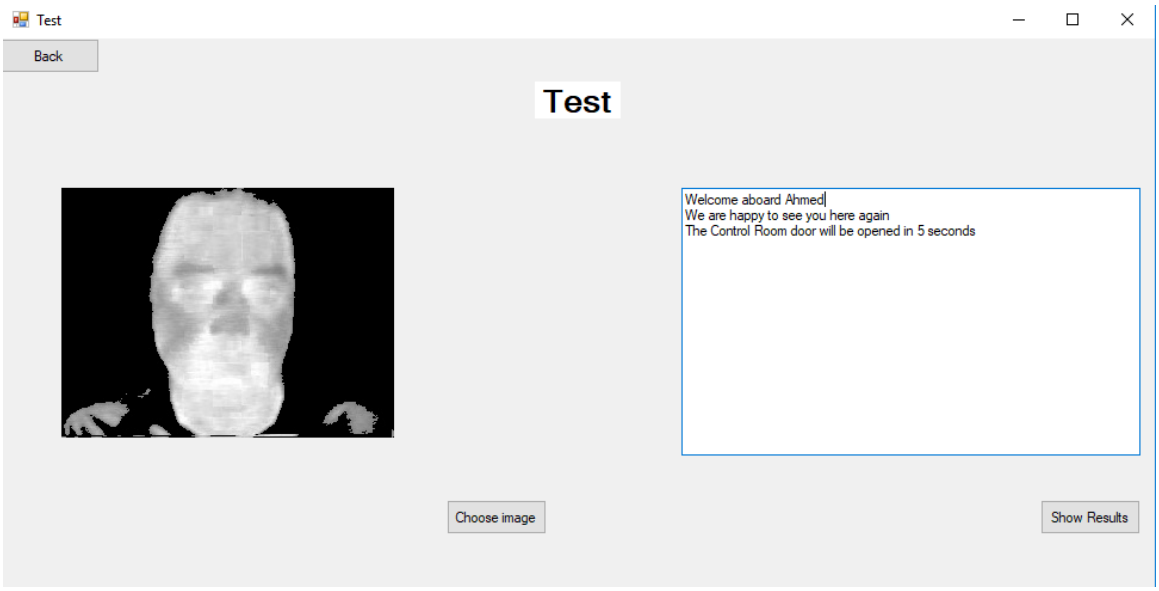


Figure 5.18: Test page screen after uploading an image and having the recognition result

5.5.3 Screen Objects and Actions

First the admin has to enter his username and password then he will be able to access the capturing page, where he can add or capture a new image for a new user and use the

preprocessing and the feature extraction algorithms and then save the image, next he will add the information of the user and the rooms he can access,Finally the data will be saved in the database.

5.6 Requirements Matrix

Functional Requirements	Status	SRS	SDD	Technical Specification
Admin Login	In progress	_	_	
User Enrollment	In progress	_	_	
Capture Training Images	Completed	x	x	
Segmenting Training Images	Completed	x	x	Adaptive threshold
Features Extraction from training images	Completed	x	x	Extract feature vectors
Uploading testing images	Completed	x	x	
Segmenting Testing Images	Completed	x	x	Adaptive threshold
Features Extraction from testing images	Completed	x	x	Extract feature vectors
Recognizing testing images	Completed	_	x	Classifying based on feature vectores

Figure 5.19: Requirements Matrix

Chapter 6

Evaluation of the proposed system

6.1 Experiment 1/3: Accuracy Testing

In order to achieve the best accuracy and recognition rate, a comparative study had to be done in order to come up with the most accurate combined algorithms.

Dataset

An available online dataset called Terrarvic IR Facial dataset[2] is the one that we used on implementing our system. Itontains 20 classes of 20 persons, each person has thermal face images that ranges between 210-270 Images. Images dimensions are 320*240. All faces include full frontal, left and right profile images.

Using Support Vector Machine (SVM)

First, using Support Vector Machine (SVM) classifier, we started by having images of 5, 7 and 10 for each of the three classes with the following features extraction algorithms (Thermal Features, Scale-invariant feature transform (SIFT), Histogram of Oriented Gradients (HOG) and KAZE). With one testing image for each class. We are aware that these number of images for the training and testing stages are not enough, but the main reason for this is that we faced some troubles in adding more images using the SVM classifier we are aiming

to increase their number in the future to test its accuracy.

Algorithm	Number of Training Images	Number of Classes	Accuracy
SIFT	5	3	60%
	7		71.42%
	10		**80%**
Thermal Features	5	3	40%
	7		57%
	10		60%
HOG	5	3	60%
	7		57%
	10		70%
KAZE	5	3	60%
	7		57%
	10		60%

Figure 6.1: SVM Results

Using Neural Networks (NN)

We started training an testing the Neural Network with 1171 images, taking 70% for training and 30% for testing. Using Neural network with 2 Feature extractors, we came up with those results.

- NN with HOG Descriptors;
    - 150 input neurons: 82%
    - 512 input neurons: 80.3%
    - 1250 input neurons: 80%
- NN with KAZE Descriptors;
    - 150 input neurons: 96.42%
    - 512 input neurons: 80%
    - 1250 input neurons: 81.1%

Features	Input network Size	Dataset		Classes	Accuracy
		Training (70%)	Testing (30%)		
HOG Descriptor	150	891	280	9	82%
	512				80.3%
	1250				80%
KAZE Descriptor and Detector	150	891	280	9	96.42%
	512				80%
	1250				81.1%

Figure 6.2: Neural Networks Results

From the table above, we had the best accuracy on testing Back-propagation Neural Networks classifier with an input size of 150 neurons with KAZE descriptors where it reached 96.42% on Terrarvic IR dataset.

Here is a chart showing the related work recognition accuracy comparing to our proposed method. Which shows that our method is better than three of them, only one work using CNN has a higher accuracy that our method. Notice that every one has different dataset for training and testing, and also different number of training images as mentioned before in the related work section.

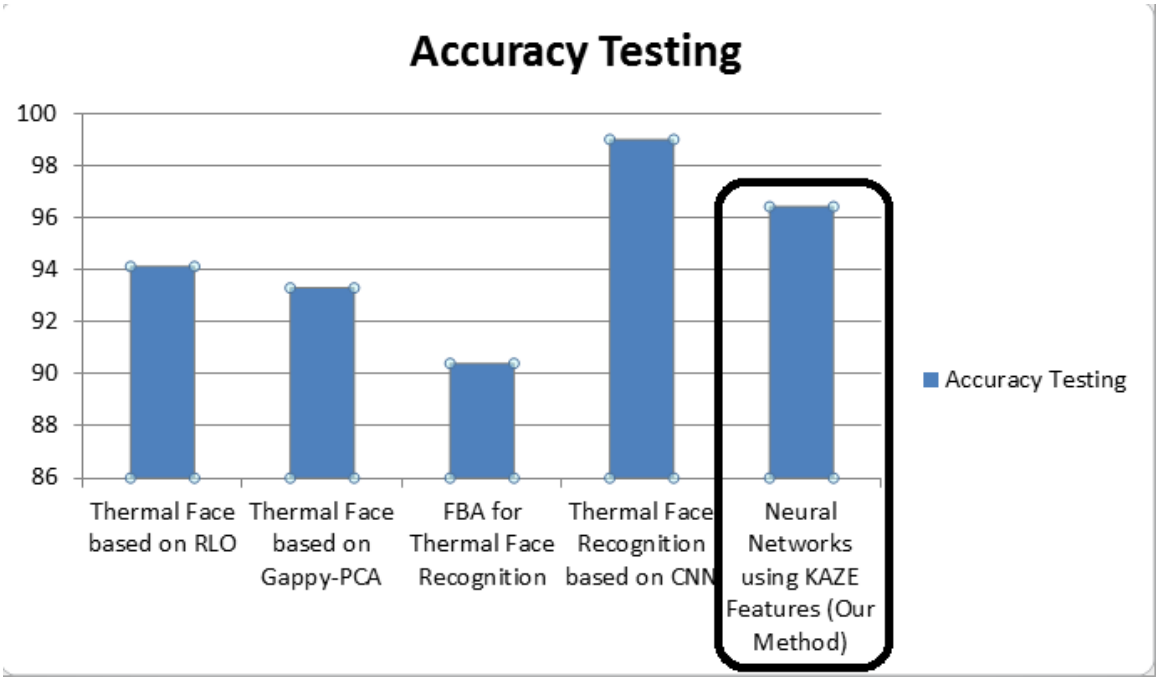


Figure 6.3: Reached accuracy comparing to related work

6.2 Experiment 2/3: Domain Accuracy Testing

On testing the algorithms that we settled on in the application, we tested 9 classes, each one has 40 images and we tested their accuracy and whether they recognized them correctly or not in the table below:

Class	A	B	C	D	E	F	G	H	I
A	40	0	0	0	0	0	0	0	0
B	0	40	0	0	0	0	0	0	0
C	0	0	40	0	0	0	0	0	0
D	0	0	0	38	2	0	0	0	0
E	0	0	0	0	40	0	0	0	0
F	0	0	0	0	0	37	1	0	2
G	0	0	0	0	0	0	40	0	0
H	2	0	1	0	0	0	0	35	0
I	1	0	0	0	0	1	0	0	39

Figure 6.3: Table shwoing each class with the corresponding recognition result

6.3 Experiment 3/3: User Experience

We had 10 people testing and giving their impressions on our system. 3 of them were domain experts, which are; Eng Amr Salem (Communication Systems Consultant), Nader Kamal Hafez and Ali Abd El-Halim Mahmoud (Engineering and Development of Communication System General Manager). The other 7 were our friends of ours who tested the system. After testing the system, all of them answered a questionnaire we made for them.

Responses for the questionnaire

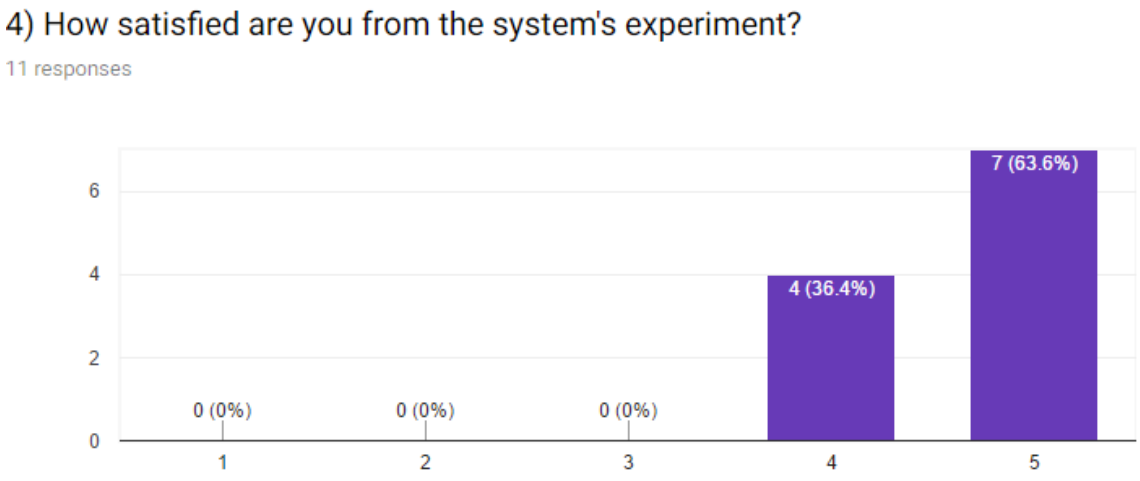


Figure 6.4: Questionnaire Results

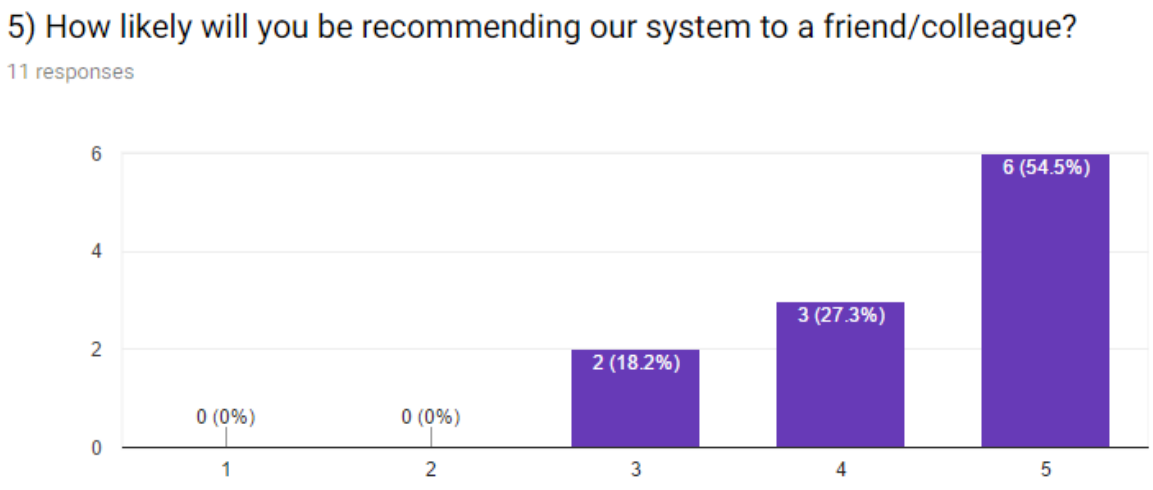


Figure 6.5: Questionnaire Results

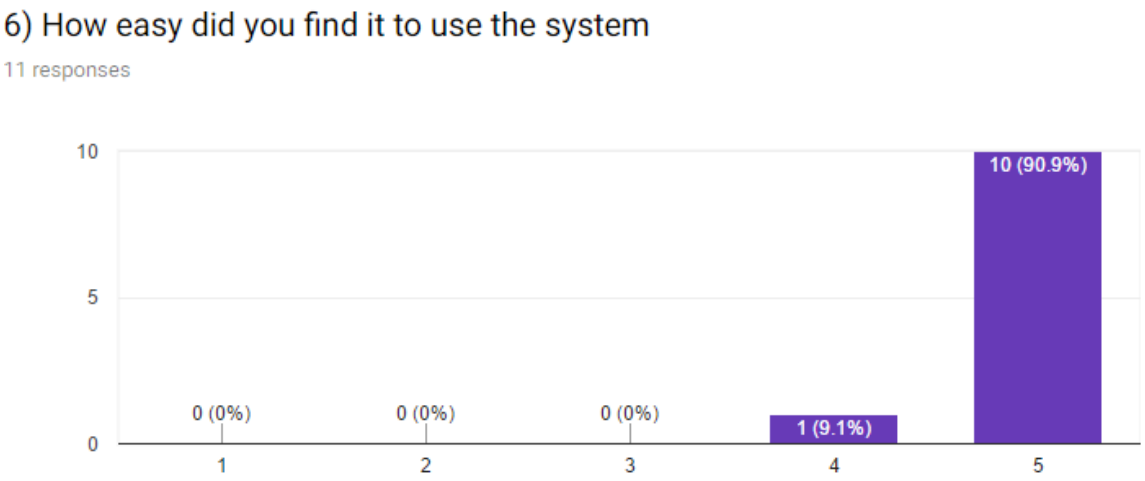


Figure 6.6: Questionnaire Results

Chapter 7

Conclusion

One of the main challenges that faced us, was coming up with the most accurate algorithms that can serve us in our goal and achieve an accuracy that can be proper enough to be used in such a security application with many classes. The application can be used in deciding whether to grant access to a specific person or not by recognizing his face, then checking his authority and whether he has access to this specific room or not which requires a very high accuracy and a fast recognition system.

7.1 Future directions

In order to complete this system, a thermal camera that gives feed of thermal images is needed. It will provide the system with the needed thermal images of the desired people in order to take action depending on the person's recognition result and authorities to be working in real-time application. Recognizing multiple face images at the same time is also a goal that would be achieved in the future to give the system more flexibility and reliance. Having a professional GUI to the system is also an important step in the future to make it easier for its users. Testing the SVM classifier with more training and testing images in order to achieve higher accuracy. Start learning Convolutional Neural Networks (CNN) which have achieved higher accuracy before in order to start from what they have reached.

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