FACIAL RECOGNITION TECHNOLOGY, A GROUNDBREAKING TECHNOLOGY FROM THE PAST DECADES

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A project report submitted to the
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Declaration

The project submitted herewith is a result of my own efforts in totality and in every aspect of the project works. All information that has been obtained from other sources had been fully acknowledged. I understand that any plagiarism, cheating or collusion or any sorts constitutes a breach of TAR University College rules and regulations and would be subjected to disciplinary actions.

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Abstract

Nowadays, Facial Recognition System is widely well known in the community and has been further developed to contribute to the society aiming to ease human's work. Facial Recognition is a type of computer application using trained databases to recognize specific individual (human face) through video capturing and processing digital images to be then analyzed, compared, and identified whose identity this facial image belongs to. The current existing attendance system have yet to apply facial recognition due to the challenges faced and the limitation of technologies. However, facial recognition is actually feasible to speed up the time taken for attendance taking as well as the accuracy and the effectiveness of storing these attendance data.

The project includes a deep study regarding the current existing attendance system and the facial recognition through literature review. A prototype is to be developed to seize the opportunity of adding the facial recognition to attendance taking. Other than that, the requirements that is to be considered as well as the methodology to accomplish this prototype has been listed down. The system design and project flow shall also be delivered for clearer understanding. After the development of the prototype, a series of experiments and system testing is carried out to validate the performance of the prototype to determine whether or not this new technology is feasible to be implemented with the current existing attendance system.

The project is developed using Visual Studio Code in Python Language with the help of OpenCV and Haar Cascade Classifier Algorithm as well as LBPH algorithm, on the laptop with Windows 11 Operating System. The prototype aims to determine the accuracy of attendance taking using 20 testers in between the age 18 to 26 with male and female of equal number and hopes for the results to be at least 80%. Through this journey there are many challenges faced, but at the same time the discovery is rewarding.

Acknowledgement

This project has been benefited greatly from the support of many people, some of whom I would like to sincerely express my gratitude here. Firstly, I would like to express my gratitude towards my supervisor, Ms. Mazlinda Binti Nezam Mudeen who have spent most of the time answering my doubts, putting effort in guiding and teaching me chapter by chapter. I believe she definitely deserves special recognition for her calm and friendly manner which allowed her to provide help and suggestions graciously while she has tons of work to focus on at the same time. Thanks to her, I managed to learn more regarding this topic, to complete the work not only on the right track but also on time.

Next, I would like to thank my family who supported me in all possible aspect such as in terms of mentally, physically, financially and etc, they encouraged me, gave me the determination to keep going. There are times that I felt worn out but thanks to them I was able to keep myself together and continue my education journey since young till now which has proven to be crucial as knowledge is the best wealth one can possess.

There are 24 other people who had helped me to complete this project, as well. Thanks for your support, Ammeshajeet, Chong En Han, Chuah Jia Xuan, Elisha Hor Zi Xuan, Foo Jia Qi, Heng Zhi Xuan, Jack Siow, Lee Quan Jin, Lee Xin Wei, Lee Xin Yun, Lee Ying Shan, Lim Shin Yie, Mervin Leo, Mok Yuen Yua, Seah Wei Ming, Siew Wai Han, Tan Choy Yin, Tan Yoke Shuen, Tan Zhe Yan, Tia Wan Tong, Wong Kar Lok, Yap Wei Xiang, Yap Yong Yi and Yee Jian Le. They are the most important people as they are the people who assisted me to complete the 25 sets of facial databases.

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Chapter 1

Introduction

1 Introduction

Facial recognition is a category of biometric software that maps an individual's facial features mathematically and stores the data as a faceprint. The software uses deep learning algorithms to compare a live capture or digital image to the stored faceprint in order to verify an individual's identity. The facial features of a human work the same as their fingerprint, every person has their own specific pattern so that it can be used to identify a person's identity. Every face has numerous, unique characteristics, as well as the peaks and valleys that allow us to differentiate someone from another so that they can be made up as facial features.

Face recognition system is part of facial image processing application and its applicability is easier and working range is larger than other biometric information processes such as fingerprint, iris scanning and signature (Gürel and Erden, 2012). It is a biometric technology which is based on the identification of facial features of a person (Li et al., 2020).

1.1 Research Question

The aim of this study is to develop a prototype for facial recognition to be used for attendance recording purposes in the Faculty of Computer Science and Technology (FOCS), Tunku Abdul Rahman (TARUC).

In order to develop this prototype, five research questions have been identified as below:

I. What are the challenges faced in facial recognition?

II. What are the advantages or contributions of facial recognition in Software Industry?

III. What are the general facial recognition steps?

IV. What are the common algorithms used to develop facial recognition?

V. What is the hardware or devices that can be used for the prototype development?

1.2 Research Objectives

In order to complete this study, some objectives have been stated as follow:

I. To identify challenges that faced in facial recognition.

II. To analyze advantage and contribution in software industry.

III. To analyze potential algorithms for facial recognition.

IV. To develop a face recognition prototype to identify a person based on facial features

V. To validate the proposed face recognition prototype in terms of accuracy and performance.

1.3 Research Background

The goal of this project is to develop a face recognition prototype that is not commonly used in the higher education of Malaysia. Not only a background study will be conducted but also necessary comparison to different system configurations / parameters will require a respective dataset (either from public online or perform own data gathering) The prototype developed is supposed to be able to recognize 10-20 faces from different people. After that, the results of different methods shall be compared, such as the accuracy, precision, efficiency and so on under a set up real-life scenario. Based on the results, a brief explanation will be given including but not limited to the performance of the prototype, the advantages and disadvantages, as well as the characteristics of the methods we used for face detection and recognition.

By applying facial recognition that is not commonly used in the higher education campus yet. Therefore, the accuracy and performance of this prototype is put to the test to see whether it can be used to replace the current existing attendance taking system. The function that will be included in the prototype is the face detection, feature extraction, facial recognition, and personal information display through well prepared database using the computer webcam. The main focus is to determine how well the prototype is able to recognize a student face accurately, thus the attendance taking part will not be included since the technology for registering student's attendance has been far more mature to be improvised.

This is because the current system requires the lecturer and tutors to spend relatively longer time to take the students' attendance. Not only that, but it is also undeniable that the existing way of taking attendance has given the students many opportunities to fake their attendance. For example, a lecture class consists of an average of 100 students which is difficult for the lecturer to keep track of every student's attendance. Considering the fact that most people nowadays possess an advanced smartphone with a higher quality camera which makes face recognition much more feasible.

1.4 Project Plan

Milestone	Milestone Goal	Start Date	End Date
Concept Approval	Feasibility studies and project concepts is approved.	11/11/2021	10/12/2021
Background Research	Brief discussion of major theories and models related to the research problem have been studied.	11/12/2021	21/02/2022
Solution and Algorithm Review	Solution and algorithm which is used in facial recognition has been reviewed and compared, the most appropriate methodology has been used to apply in this research.	22/02/2022	25/03/2022
Prototype Development	A prototype has been coded from concept to implementation for testing purpose	26/03/2022	26/06/2022
Collect Data Set	Collect relevant data set.	26/03/2022	26/05/2022
Data Set Pre-processing	Analyze data set to perform pre-processing.	27/06/2022	10/07/2022
Experiment	Apply and implement the algorithm to data set.	10/07/2022	31/07/2022
Result Review	Review the result produced with the algorithm and data set is accurate to the desired result.	01/08/2022	15/08/2022
Final Project Report	The final report and all associated deliverables are correctly filed and under perfect condition to be submitted	15/08/2022	31/08/2022

1.5 Thesis Outline

Chapter 2: Literature Review

This chapter shows that the research project will go deeper towards a specific part, this chapter will contain full with journal and literature which is related to the research project, the facial recognition technology.

Chapter 3: Methodology

This chapter is all about the general project flow and requirements for carrying out the research. The requirements are categorized as functional and non-functional requirements. The use case diagram and description are added to explain the overall prototype. The hardware and software used is further list down as well.

Chapter 4: Data Collection and Design

This chapter includes data collection and any preprocessing about the collected data, the algorithms (for face detection, feature extraction and face recognition) to carry out the experiment, and the way to analyze collected data set. Other than that, the design and architecture of the prototype has been included. For example, UI design, ERD design, Class Diagram and Sequence Diagram.

Chapter 5: Implementation and Testing

This chapter briefly goes through how the prototype is implemented, the crucial coding parts that build up special features of the system. Moreover, the test plan is shown to describe how testing will be carried out to validate the prototype in terms of functionality, performance, reliability and so on. Lastly, some test cases are listed out that include detail steps on how the system testing proceed, and the outcome of each test case is determined.

Chapter 6: Discussions and Conclusion

This chapter focused on the evaluation of project and system developed that were embarked on. The project evaluation has included technical problems faced and solutions to it, unsolved technical problems for future enhancement, the contribution of the system developed towards the involved users and etc.

Chapter 2

Literature Review

2 Literature Review

2.1 Current Existing Attendance Taking System

2.1.1 6-digits Attendance System

The current existing attendance taking system that Tunku Abdul Rahman University College implements is the 6-digits Attendance System through the school mobile application, namely TARC App. The process is that during the physical class (f2f) the lecturer may generate a 6-digit code as they login the TARC App with their staff account and to announce the code to the students during the breaktime of a class. The students on the other hand should login their student account in TARC App and key in the 6-digit code accurately within the class period using the school's Wi-Fi only in order to take their attendance successfully.

The advantage of this system is that this ensure that the students should be in campus and in class to know the 6-digit code and to check in within class period. However, there is a small bug within which means that another student with the information of an absent student's user ID and password is able to take attendance for him or her as well, given that the mobile device that is used is at the school campus, using school Wi-Fi is enough to do so. Therefore, this attendance system works for those who are positively eager to attend class but not able to prevent those who wants to skip class. As the school policy suggest that student's attendance below 80% are barred from participating the Final Examination, students used this tactic to skip class while maintaining their attendance on check.

2.1.2 Google Form

Some university uses google form to take attendance, such as Universiti Teknikal Malaysia Melaka (UTeM). The lecturer will share a google form consisting some question regarding the student's details like their name, student email, student ID and their group number. Other than that, depending on the lecturer's preference, he or she may even include some question regarding the topic learnt for the day to test the student's understanding for the day

The reason behind this system is because of the efficiency and effectiveness of recording student's attendance as google form can easily compute and generate report for attendance. Not to mention that, the google form can include some questions that would be able to test the student's understanding and to know their level, therefore the lecturer can pay attention to the students who are not performing as well as the others. However, the downside with google form is that it relies on the google company, and if google undergo server maintenance, the students are not able to take attendance as well. Other than that, google form is not easy to create and therefore consumes time and energy to be prepared for each class.

2.1.3 Traditional Attendance Taking Method

Not every school has advance attendance taking system, few of them remains using the old-fashioned attendance taking method that is tedious and ineffective. For example, the Technology University of Shannon, Ireland as well as Dasein Academy of Art, Malaysia uses calling students name one by one and asking student to write their name on a piece of paper as a way of evidence to show that the students are present. From here, we can deduce that these school does not focus or enforce the student's attendance as strict as Tunku Abdul Rahman University College. This is because, these school does not ask for student's attendance to be at least 80% present before they are given the right to participate the final examination. Thus, these school only record the attendance for report purpose and not to ensure student attend their classes.

In conclusion, this type of attendance taking method usually waste a lot of the class time, is rather inaccurate and ineffective. Not only that student can easily fake their attendance, the lecturer may easily make mistakes such as losing the attendance list in paper or missed taking a student's attendance by accident. This will result in the lack of reliability between students as well as the lecturer himself and the attendance taking fails its purpose of existing.

2.2 The Procedure of Facial Recognition

As the digital world and real-world merge more and more together, identifying users and improving information security accurately and effectively has become an important research topic (Li and Cha, 2010). Lin (1997) also suggests that the need to maintain the security of information or physical property is becoming both increasingly important and increasingly difficult in today's networked world. Thus, the face recognition system is widely implemented in several social places and applications to strengthen public safety such as on the bank users to verify their identity which greatly enhances the security (Mohammad, 2020). There are a total of three steps involved in the face recognition procedure: face detection, feature extraction and face recognition as shown in Figure 2.1 below that is proposed by Chao (2016).

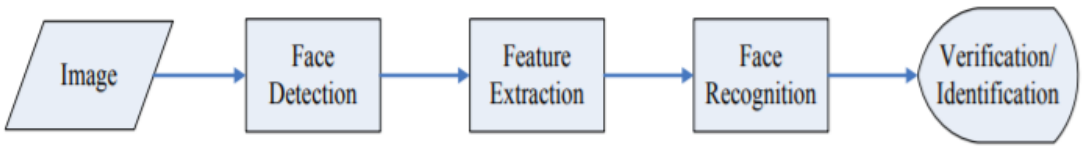

Figure 2.1 Configuration of A General Face Recognition Structure

There are a few problems to be solved in order to achieve successful face recognition:

1. Allow the camera to look at a picture and find all the faces in it.
2. Being able to focus on each face and to understand that even if a face is turned in a weird direction or in bad lighting, it is still the same person.
3. Be able to pick out unique features of the face that you can use to tell it apart from other people— like how big the eyes are, how long the face is, etc.
4. Compare the unique features of that face to all the people you already know to determine the person’s name.

Apparently, these problems are like a pipeline, a related problem sequence that we solve one by one each step leading us closer to our ultimate goals. In other words, we need to chain these four steps with several machine learning algorithms separately and pass the results from the current step to the next step.

2.3 Challenges with Facial Recognition System

2.3.1 Technological Challenges

1. Aging

Face in the form of various textures entail characteristics value changes over a period of time and reflect as aging, which has a prompt importance in face recognition as shown in Figure 2.2. Aging factor in face recognition systems in different age groups for various face sets over a period of time calculated for accuracy checking. Aging effect descriptor for various age groups and classification need similarity measure for age discrimination (Shilpi Singh, 2018).

Figure 2.2: Same Person Photographed (a) at a Younger Age and (b) at an Older Age.

2. Facial expressions

Different face expressions may deeply affect the accuracy of the face recognition as one who is smiling or in an angry state can be hard to identify as the same person, such as the one shown in Figure 2.3. From research of nowadays face recognition technology, the results where they achieved a recognition rate of 97.0% and verification rate of 99.01% for different faces either having neutral expressions or having non-neutral expressions only. (Shilpi Singh, 2018)

Figure 2.3: Various Facial Expressions that Reflect Emotions such as (a) Anger, (b) Disgust, (c) Sadness or (d) Happiness.

3. Facial advances

Face recognition becomes more challenging in cases when an image differs by surgical variations of faces for increasing beauty. Coarse-to-fine strategy was used to identify landmarks under different poses in 3D face. External, internal features, facial expressions and face dynamics findings are easier to discriminate in isolated features rather than embedded features (Shilpi Singh, 2018).

4. Pose variations

Head's movements, which can be described by the egocentric rotation angles, i.e., pitch, roll and yaw, or camera changing point of views could lead to substantial changes in face appearance and/or shape and generate intra - subject face's variations as illustrated in Figure 2.4, making automated face recognition across pose a difficult task.

Figure 2.4: Illustration of Pose Variations around Egocentric Rotation Angles, namely (a) Pitch, (b) Roll and (c) Yaw.

2.3.2 Social Challenges

1. Data Privacy Concern

Face recognition data include millions of images and video files. Also, it consists of the "maps" created when systems scan people's faces. Ultimately, face recognition data gets stored in servers, usually accessible via the cloud. As with any other computer system, it is vulnerable to hackers (Rodriguez, 2021). Although the systems developed nowadays have strengthened their firewalls and mostly are able to protect themselves from identity theft, no one can assure that the information will not be fallen into the wrong hands. What worries people the most is that companies could share or even sell this data to third parties,

2. Low Reliability

According to a study by the Massachusetts Institute of Technology (MIT), misidentifications are rampant in facial recognition which leads to its unreliability. Today, other biometrics methods, like fingerprints scans, are more reliable than facial recognition. For example, low illumination, image or video quality can lead to false positives. Other than that, slight changes in camera angles or personal appearance can cause errors as well, a person won't always stand still or maintain the same haircut all the time which becomes a serious limitation to this technology.

3. Racial Bias

Reports show that facial recognition isn't as effective at identifying people of color and women have surfaced. One common misconception is that face recognition is inherently bad at identifying women or people of color. Yet, that is not the case. Facial recognition requires a dataset with a considerable quantity of examples to learn how to identify people. Unfortunately, the first implementations didn't include enough people with diverse characteristics (Rodriguez, 2021). Thus, the solution for that is to feed the facial recognition system with diverse datasets with people of all races and genders, not just of a particular group. The Gender Shades project revealed discrepancies in the classification accuracy of face recognition technologies for different skin tones and sexes. These algorithms consistently demonstrated the poorest accuracy for darker-skinned females and the highest for lighter-skinned males as shown in Figure 2.5 (Alex Najibi, 2020). Independent assessment by the National Institute of Standards and Technology (NIST) has confirmed these studies, finding that face recognition technologies across 189 algorithms are least accurate on women of color.

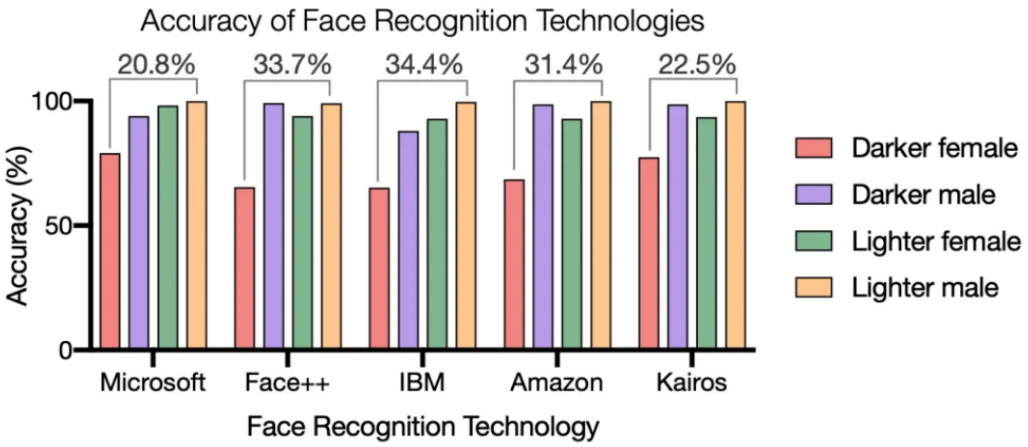

Figure 2.5: Auditing five face recognition technologies

4. Lack of Regulation

Governments around the world are yet to pass legislation around face recognition (Rodriguez, 2021). As a result, there is no consistent framework for its use and limits. The tendency of mass adoption of face recognition is high; however, the regulators and laws are not catching up as fast as expected. Based on Figure 2.6, we can confirm that a 59% majority of U.S. adults think it is acceptable for law enforcement agencies to use facial recognition technology to assess potential security threats in public spaces, while just 15% find this unacceptable. The rest are either unsure if this is acceptable or have not heard of facial recognition technology in the first place. This is based on a research report which was written by Aron Smith, 2019.

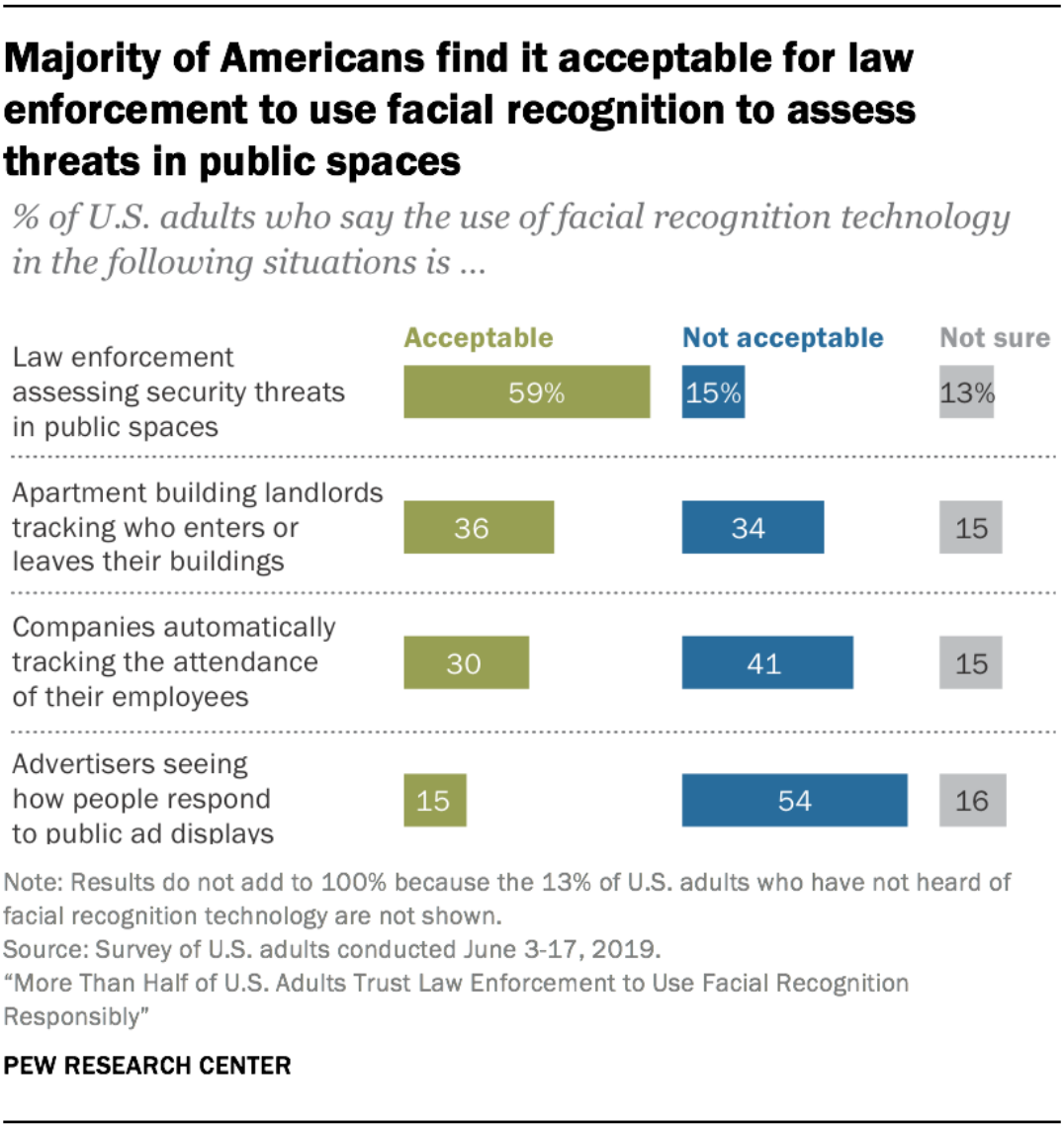

Figure 2.6: Auditing five face recognition technologies

2.4 Advantages and Contribution of Facial Recognition

Facial recognition software (FRS) is defined as a biometric tool used to match faces in images, usually from photos and video stills, against an existing database of identities. It can be broken down into three parts — detection (finding a face in an image), analysis (face mapping), and recognition (confirming identity) (Ramya Mohanakrishnan, 2021).

The advancement in facial recognition technology has improved the living standards of the country in all sorts of industry. One of the most significance benefits is how effectively capturing suspects and improving the public security has been since the technology is applied by the local police department. Not only that, face recognition system has great potential uses in retail shop, hospitality sector, banks industry as well as the airport. However, many of us have overlook the advantages and contribution that face recognition comes with in terms of the IT (Mobile Application) industry which has successfully penetrate into our everyday life.

1. **Facial Recognition in Account Management**

   Facial Recognition allows users to unlock their phone or login their account using only their face, which works just the same as fingerprints. The benefits are its fast processing nature, and does not require any contact with users, easy to be handled with only one hand that controls where the front camera is, most importantly, users will not need to remember their passwords, or username. In short, facial recognition prevents the inconveniences caused by traditional way of assessing their account and saves more time. Early this year, Juniper Research reported that facial recognition hardware such as Apple's FaceID is the fastest growing form of biometric smartphone hardware. It is estimated that over 800 million smartphones will be using them by 2024 (Ramya Mohanakrishnan, 2021).

   Other than that, online banking application also may benefit from face recognition technology to improve their account security as there will be no passwords that hackers could compromise from. Even if hackers were able to stole your photo database, it would still be of little use, as "liveness detection," prevents unauthorized third parties to use them for impersonation purposes.

2. Facial Recognition in Photo Tagging Feature

Another example of facial recognition technology usage is shown by the auto photo tagging feature on Facebook or even Google Photos. Social media and tech giants like these, maps a user to the face in the photo by sorting through their existing database of uploaded images (Ramya Mohanakrishnan, 2021). Since facial features are much more complex than other existing biometric methods like fingerprints and the eye's iris, facial recognition software tools require complex, artificially intelligent algorithms. The people album in photos on iPhone devices can also recognizes the faces of people in the users' photos and groups them together. Thus, the phone owner can name the people in their photos and mark their favorites people. Depending on the number of photos that one has, they can watch a Memory movie of the people they have saved in the album.

However, it is true that Facebook have shut down this feature and people who've opted in will no longer be automatically recognized in photos and videos. Not only that, Facebook will delete more than a billion people's individual facial recognition templates to weigh the positive use cases for facial recognition against growing societal concerns, especially as the regulators have yet to provide clear rules (Jerome Pesenti, 2021).

3. Facial Recognition in Healthcare Application or Entertainment Purposes

Face2Gene is a face detection app created for healthcare experts, and thus it is not opened for public use. It examines improved patient evaluation with next-gen phenotyping, but it is not feasible to use this app without proper medical training. The facial recognition app development boosts the clinician's confidence and bioinformatics by prioritizing genetic disorders & variants in the clinic & lab (Harnil Oza, 2021). For example, the Face2Gene provides features that support the experts to find genetic disorders, and to track dysmorphic features.

Other than that, face recognition can be used in other apps for entertainment purposes. An example is the Face DNA Test which is a face recognition app that is much more advanced, it allows users to scan their facial feature with another and to compare if these 2 people could possibly be related. Its main function is to validate the relationship between family members with the app's algorithms. It is said that even the baby pictures can even be used to acquire precise results.

4. Facial Recognition in Attendance System

Industrial floors worldwide are plagued by time fraud, which is still one of the most common work ethics violations. The vast majority of workers are honest. Even so, there is a minority that engages on buddy favors from staff members or security personal to skip work (and still get paid). Time fraud is not only detrimental to companies but also honest contributing workers. Another benefit of face recognition technology is that it could end time fraud. The workers will only need to pass face-scanning devices to check-in for work. Paid hours begin from that moment onwards until the worker checkout using the same system. The process is fast and effective, workers will not need to prove their identities or clock in with their ID card like the old-fashioned way. The attendance system can also be modified for education taking attendance purpose as well.

2.5 Face Detection Method

Face detection is an AI-based computer technology that can identify and locate the presence of human faces in digital photos and videos. Detection begins with the extraction of the face out of the image fed into the system. Subsequently, various features on the human face are marked. Certain features of the face do not change with age or size. These include the distance between the eyes, the depth of the eye socket, and the shape of the nose. There are around 80 such features called 'landmarks.' The measurements of these landmarks are then put together to create a code. This code is called a 'faceprint,' and it is unique to every person.

When it comes to facial recognition, face detection is necessary for the algorithms to know which parts of an image (or video) to use to generate the faceprints that are compared with previously stored faceprints to establish whether or not there is a match. Face detection applications use algorithms that determine whether images are positive images (i.e., images with a face) or negative images (i.e., images without a face). To be able to do this accurately, the algorithms must be trained on huge datasets containing hundreds of thousands of face images and non-face images. Haar Cascade Classifier, Principal Component Analysis and RGB Filter are several examples of face detection algorithms that can be used to identify faces in images or videos which will be further explained in the following sub-section. Other methods of face detection include Histogram of Oriented Gradients (HOG), Edge Detector, Skin Texture Analysis, Thermal Cameras and so on.

2.5.1 Haar Cascade Classifier

Haar Cascade is an object detection method used to locate objects on images. The algorithm learns from a large number of positive and negative samples — the former contains an object of interest, and the latter contains anything other than the object you are looking for (Technologies, 2021). After training, the classifier can find an object of interest on new images. The method was used in criminal identification in combination with the local binary pattern algorithm to recognize faces. The Haar cascade classifier uses 200 (out of 6000) features, which ensures an 85-95% recognition rate even with varying expressions.

Compared to other object or facial features detection of using the intensity values of a pixel, Haar Cascade Classifier uses the change in contrast values between adjacent rectangular groups of pixels. The contrast variances between the pixel groups are used to determine relative light and dark areas. Two or three adjacent groups with a relative contrast variance forms a Haar-like feature just like what as shown in Figure 2.7. Haar-like feature are used to detect images and can be scaled accordingly by alternating the size of the pixel group being examined.

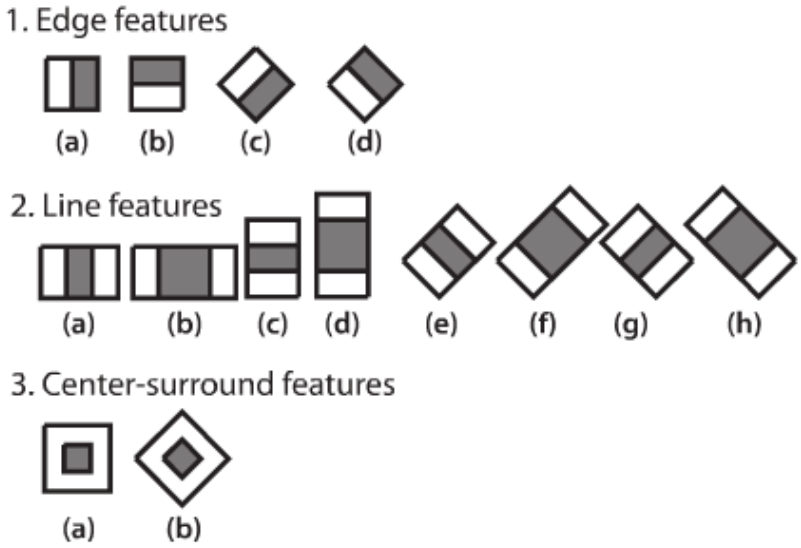

Figure 2.7: Common Haar Feature used in Haar Cascade Classifier

To detect human facial features, such as the mouth, eyes, and nose, the Haar cascade classifier must first be trained. To train the classifiers, two set of images are needed. One set contains an image or scene that does not contain the object, in this case a facial feature, which is going to be detected (Xing Yong, 2016). This set of images is referred to as the negative images. The other set of images, the positive images, contain one or more instances of the object. In order

to produce the most robust facial feature detection possible, the original positive set of images needs to be representative of the variance between different people, including, race, gender, and age (Cristinacce, D., 2003). Figure 2.8 shows how the classifier uses Haar-like feature to detect the eye region and the nose bridge from an image sample of a human face.

Based on an experiment carried out using the FERET Database in the early days, we can conclude that the classifiers have a high rate of detection, however the false positive rate is also quite high. Since it is not possible to reduce the false positive rate of the classifier without reducing the positive hit rate, a method besides modifying the classifier training attribute is needed to increase accuracy. There are several ways to do so, one involving regionalization to increase the detection rate. By changing the height and width parameter to more accurately represent the dimensions of the mouth and retraining the classifier, the accuracy should increase as well. Other than that, limiting the region of the image that is analyzed for the facial features will also help improving the accuracy since we have reduced the area to be analyzed, the existing area that would produce false positives will decrease at the same time.

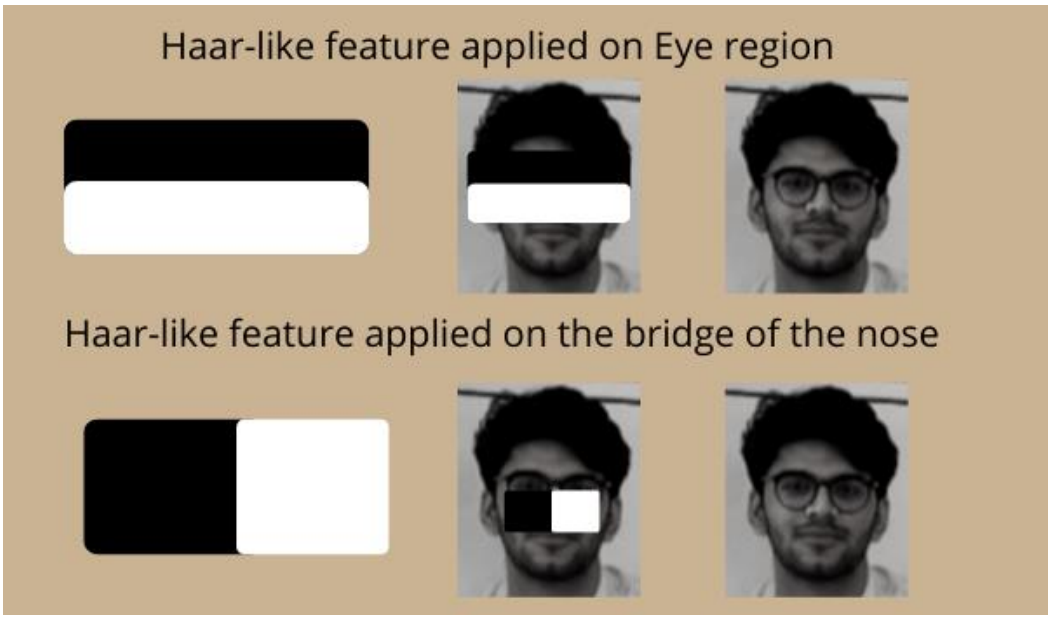

Figure 2.8: Example of Face Detection using Haar Cascade Classifier

A cascade classifier refers to the concatenation of several classifiers arranged in successive order. It makes large numbers of small decisions as to whether it's the object or not. The structure of the cascade classifier is of a degenerate decision tree. The Cascade Classifier Architecture in figure 2.9 describes how the system works. The speed of the cascaded detector is directly related to the number of features evaluated per scanned sub windows which depends

on the images being scanned. As proposed by Paul Viola and Michael Jones in 2001, this object detecting framework uses machine learning approach for object detection minimizes computation time while achieving high detection accuracy. Based on their study report of this algorithm, the results shows that the system works faster than other previous approach, especially when the feature selection was carried out using AdaBoost.

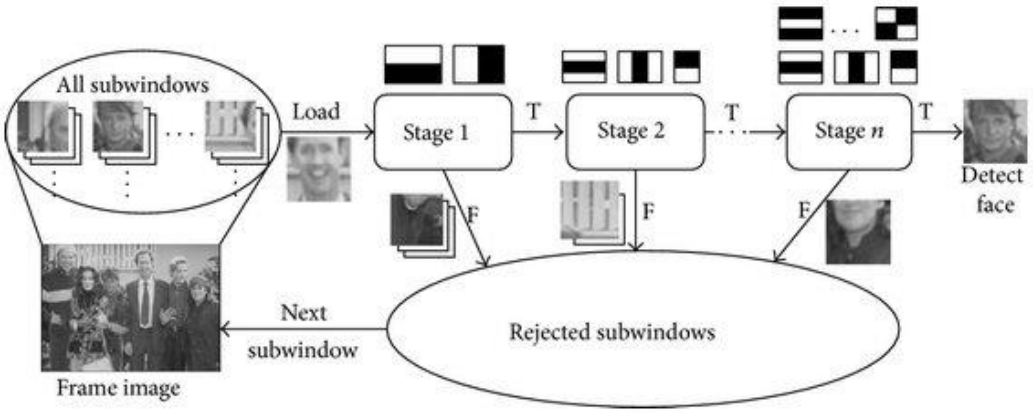

Figure 2.9: The architecture of Haar Classifier

2.5.2 Principal Component Analysis (PCA)

The principal component analysis (PCA) is a universal statistical method with many practical applications. When used in the face recognition process, PCA aims to reduce the source data size while preserving the most relevant information (technologies, 2018). It generates a set of weighted eigenvectors that, in their turn, build up eigenfaces — an extensive sets of different human face images. A linear combination of eigenfaces represents every image in the training set. The PCA is used to receive these eigenvectors from the covariance matrix of a training image set and for each image, its main components are calculated (from 5 to 200). The other components encode minor differences between faces and noise. The recognition process includes comparing the unknown image's main component to the components of all other images.

Based on the article *Face Recognition using Neural Networks* written by P. Latha, Dr. L. Ganesan and Dr. S. Annadurai, we are able to explain PCA using several formulas to derive the steps of how PCA works in facial detection. Principal component analysis (PCA) [2] involves a mathematical procedure that transforms a number of possibly correlated variables into a smaller number of uncorrelated variables called principal components (P. Latha, n.d.).

The algorithm used for principal component analysis is as follows.

(i) Acquire an initial set of M face images (the training set) & calculate the eigen-faces from the training set, keeping only M' eigenfaces that correspond to the highest eigenvalue.

(ii) Calculate the corresponding distribution in M'-dimensional weight space for each known individual, and calculate a set of weights based on the input image

(iii) Classify the weight pattern as either a known person or as unknown, according to its distance to the closest weight vector of a known person.'

Let the training set of images be $\Gamma_1, \Gamma_2, ...\Gamma_M$.

The average face of the set is defined by $\Psi = \frac{1}{M}\sum_{n=1}^{M}\Gamma_n$

Each face differs from the average by vector $\Phi_i = \Gamma_i - \Psi$.

The co- variance matrix is formed by $C = \frac{1}{M}\sum_{n=1}^{M}\Phi_n.\Phi_n^T = A.A^T$ where the matrix $A = [\Phi_1, \Phi_2, ..., \Phi_M]$.

To obtain a weight vector **Ω** of contributions of individual eigen-faces to a facial image **Γ**, the face image is transformed into its eigen-face components projected onto the face space by a simple operation $\omega_k = u_k^T(\Gamma - \Psi)$.

The simplest method for determining which face provides the best description of an unknown input facial image is to find the image *k* that minimizes the Euclidean distance ε_k.

$\varepsilon_k = \|(\Omega - \Omega_k)\|^2$ where Ω_k is a weight vector describing the k^{th} face from the training set, a face is classified as belonging to person k when the ε_k is below some chosen threshold Θ_ε otherwise, the face is classified as unknown.

Source: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.233.5636&rep=rep1&type=pdf

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The algorithm functions by projecting face images onto a feature space that spans the significant variations among known face images. The projection operation characterizes an individual face by a weighted sum of eigenfaces features, so to recognize a particular face, it is necessary only to compare these weights to those of known individuals. The input image is matched to the subject from the training set whose feature vector is the closest within acceptable thresholds. Eigen faces have advantages over the other techniques available, such as speed and efficiency. For the system to work well in PCA, the faces must be seen from a frontal view under similar lighting.

2.5.3 RGB Filter

Generally speaking, the detection of skin color in color images is a very common but effective technique for face detection. Many face detection methods from the past century came out based on locating skin color regions in the input image. Normally, the input color image is in the RGB format, these techniques always use color components in the color space, such as the YIQ or HSV formats. From the existing MATLAB functions, the YCbCr sections could save the computation time. In the YCbCr color space, the brightness information is contained in Y section; the color information is in Cb and Cr. Thus, the brightness information could be easily fixed.

RGB filter is a crucial step during face detection, which this algorithm process can be summarized in Figure 2.10 as shown below. The skin segmentation is the part where involves the RGB filter, to determine whether there is a face present or not. White balance of images differs due to change in lighting conditions of the environment while acquiring image. This situation creates non-skin objects that belong to skin objects. Therefore, white balance of the acquired image should be corrected before segmenting it (Cahit Gürel, 2012). Sometimes, some non-skin objects may be observed since their color has fallen into the skin color space

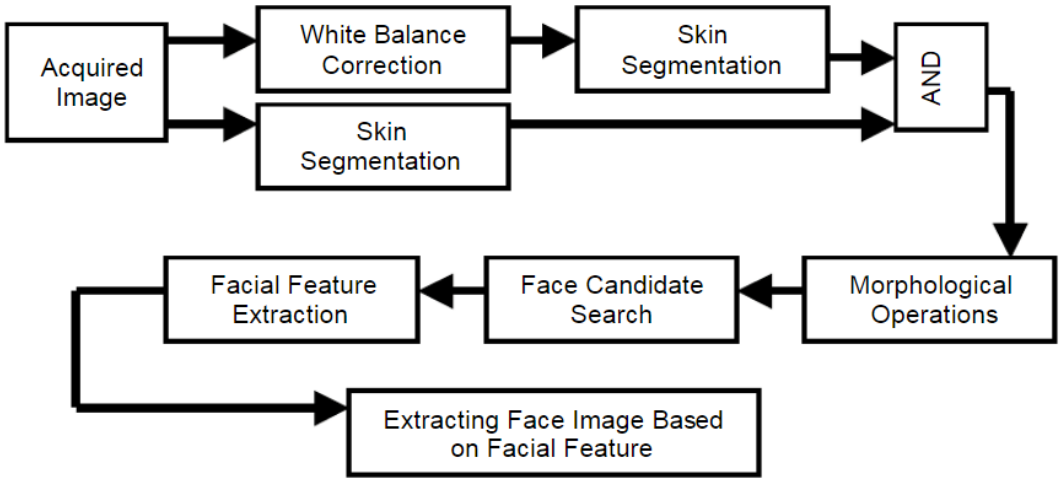


Figure 2.10: Algorithm of Face Detection Part

Results of segmentation on original image and white balance corrected image is given in Figure 2.11. The first image shows the example of an original image including a person. The second image shows the skin segmentation process without undergoing white balance correction. The third image is an image that has completed the white balance correction, although the difference is unnoticed compared to the original image. However, in the last image which carries out skin

segmentation based on the third image, the difference is significant, and a face can be detected clearly.

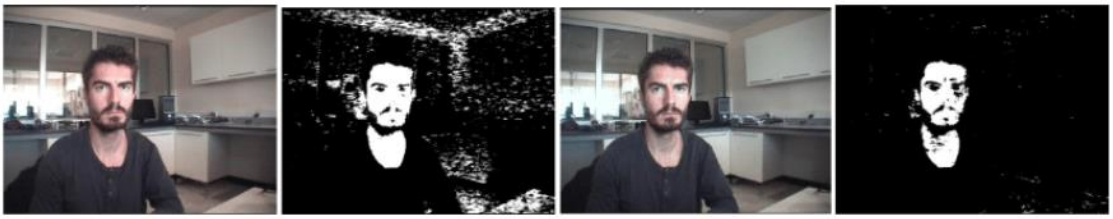


Figure 2.11: Example of taken/white balance corrected image and skin color segmentation

In the skin color detection process, the skin and non-skin will be classified by each pixel on its color section. For the skin color in the detection window was determined based on the standard deviation and mean of Cb and Cr section, include using 164 training faces in 7 input images. In feature-based approach, image is transferred from RGB color space to YCbCr color space provided Cb and Cr values satisfies following conditions: 77⩽Cb⩽127 and 133⩽Cr⩽173 (Krishna Dharavath*, 2014). The Cb and Cr components of 164 faces are plotted in the color space in Figure 2.12; whereas the histogram distribution is shown in Figure 2.13.

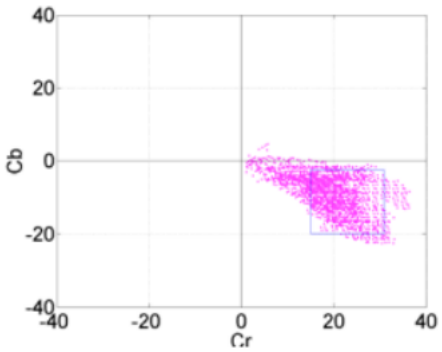


Figure 2.12: Skin pixel in YCbCr color space

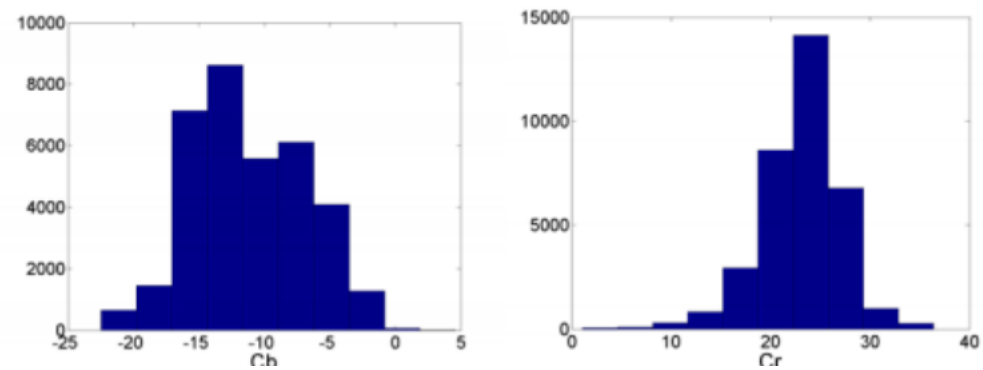


Figure 2.13: (a) Histogram distribution of Cb and (b) Histogram distribution of Cr

2.6 Feature Extraction Method

Feature extraction refers to the process of transforming raw data into numerical features that can be processed while preserving the information in the original data set. In terms of facial recognition, it is the process of extracting face component features like eyes, nose, mouth, etc. from human face image. When a photo of the face is captured, it is then analyzed during the feature extraction phase. Nowadays, 2D images are much more reliable rather than 3D because it can more conveniently match a 2D photo with public photos or those in a database. The distinguishable landmarks or nodal points make up each face. Each human face has 80 nodal points. A Facial recognition software will analyze the nodal points to get information based on your face such as the distance between your eyes or the shape of your cheekbones.

This is how the feature extraction works, and it is crucial for the next step to begin, the face recognition part, which its accuracy highly depends on the accuracy of the feature extraction method. After the analysis of one's face is completed, the information is then registered into a mathematical formula. These facial features become numbers in a code. This numerical code is called a faceprint. Similar to the unique structure of a thumbprint, each person has their own faceprint. Not to mention that there are quite a number of methods that are used for the Face Recognition such as Eigenfaces, Discrete Cosine Transform (DCT), Laplacian of Gaussian (LoG) and so on. Each method has it different functions and formulas that are used on the database images for experiments.

2.6.1 Eigenfaces

Eigenfaces is a face detection method that determines face variance in image data sets. This process involves using these variances to encode and decode faces with the help of machine learning. A set of eigenfaces is a collection of "standardized face ingredients" determined by statistical analysis of a large number of face images (Technologies, 2021). In this case, facial features are assigned into mathematical values, as this method doesn't use digital pictures but rather statistical databases. Any human face is a combination of these values with different percentages. The idea of using Eigenfaces was motivated by a technique developed by Sirovich (1987) and Kirby (1990) for efficiently representing images of faces using principal component analysis. Initially Eigen vectors are computed using covariance matrix derived from set of training images. Probe image is then projected in to the face space and the distance between mean Eigen face and probe image is computed using spatial differential operators such as Euclidian distance and Cosine distance (Krishna Dharavath, 2014).

Figure 2.14: Example of Eigenfaces from X2MVTS Database

Many prior discoveries on face recognition have overlooked the question of which characteristics of the face stimuli are crucial for identification. Eigenface removes the specifics of face forms, such as aspects that may or may not be directly related to our innate notion of face features like the eyes, nose, lips, and hair. These are the major implications of using identifying tools. The eigenface approach to face recognition was motivated by information theory, leading to the idea of basing face recognition on a small set of image features that best

approximates the set of known face images, without requiring that they correspond to our intuitive notions of facial parts and features (Xing Yong, 2016). The eigenface technique, while not an elegant solution to the general recognition problem, is a practical solution that is well suited to the challenge of face recognition. It's quick and easy to use, and it's been proven to function well in a tight space. It can also be done with the help of connectionist or neural network modules.

Fisherfaces is one of the most popular facial recognition algorithms; it’s considered superior to many of its alternatives. As an improvement to the Eigenfaces algorithm, it’s often compared to Eigenfaces and considered more successful in class distinction in the training process. Fisherfaces extend the eigenface approach by using linear discriminant analysis (LDA) instead of PCA. The key advantage of this algorithm is its ability to interpolate and extrapolate over lighting and facial expression variation. There are reports of 93% accuracy of the Fisherfaces algorithm when combined with the PCA method at the preprocessing stage (Mustamin Anggo, 2018).

2.6.2 Discrete Cosine Transform (DCT)

Images are often by default have Gaussian noise due to illumination variations. To de-noise it we work on pixel-based filtering techniques (Krishna Dharavath, 2014). Input image after preprocessing fed to a feature extraction scheme to extract features from it as shown in Figure 2.15. Discrete Cosine Transform (DCT) approach can be combined with Eigenface approach to extract face features. The recognition rate of these methods was computed with and without image pre-processing prior to feature extraction. DCT are mainly used to extract frequency domain features, whereas Zonal coding is used in DCT feature dimensionality reduction.

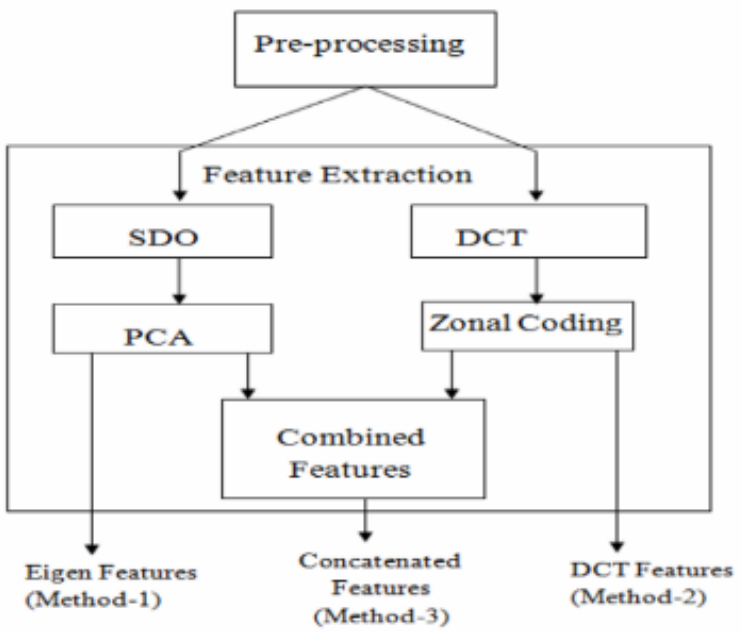


Figure 2.15: Diagram of Feature Extraction Process involving DCT

Discrete Cosine Transform (DCT) transforms spatial domain images into decoupled frequency domain images (Krishna Dharavath, 2014). That means image information is converted into DCT coefficients. These are located in the upper left corner of the DCT maximized and are the most important to represent image back.

2.6.3 Laplacian of Gaussian (LoG)

The Laplacian of Gaussian is useful for detecting edges that appear at various image scales or degrees of image focus. The exact values of sizes of the two kernels that are used to approximate the Laplacian of Gaussian will determine the scale of the difference image, which may appear blurry as a result. Unlike first-order filters that detect the edges based on local maxima or minima, Laplacian detects the edges at zero crossings i.e., where the value changes from negative to positive and vice-versa (Kang & Atul, 2019). In order to reduce the noise effect, image is first smoothed with a Gaussian filter and then the zero crossings can be found using Laplacian. This two-step process is called the Laplacian of Gaussian (LoG) operation which helps to enhance feature extraction process. The LoG kernel weights can be sampled from the equation shown at Figure 2.16 for a given standard deviation. All we need is just to convolve the kernel with the image to obtain the desired result. However, the size of the Gaussian kernel should be selected carefully, this is because if LoG is used with small Gaussian kernel, the result can be noisy. On the other hand, if a large Gaussian kernel is applied, poor edge localization may be the result.

$$LoG(x,y) = -\frac{1}{\pi\sigma^4}\left[1 - \frac{x^2+y^2}{2\sigma^2}\right]e^{-\frac{x^2+y^2}{2\sigma^2}}$$

Figure 2.16: The mathematical equation for LoG kernel weights

This is how Laplacian of Gaussian (LoG) functions in a facial recognition system. After carrying out facial detection, the face of the candidates may be extracted from the input image with modified bounding box to eliminate the chest and neck part. These face candidates will then be sent to facial feature extraction part to validate the candidates. In this case, Laplacian of Gaussian will be applied for the final verification of candidate and face image extraction. The facial feature extraction process is applied to capture facial features such as eyebrows, eyes, mouth, nose, nose tip, cheek, etc. Figure 2.17 shows that, the facial feature can be selected easily through LoG Filter. After obtaining the filtered image, the labeling operation began to determine which labels are possible to be facial features.

Figure 2.17: (a) Face Candidate Image and (b) Face Image after LoG Filter is applied

The property is used to extract the eyes and mouth which, two eyes and mouth generate isosceles triangle, and distance between eye to eye and midpoint of eyes distance to mouth is equal (Cahit Gürel, 2012). This triangle is shown in Figure 2.18 (a) as the face cover corner points are calculated. Then the face image can be extracted, the end result image is shown in Figure 2.18 (b).

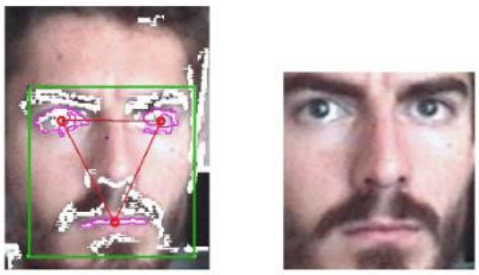


Figure 2.18: (a) Facial Feature Extractions and (b) End Result Image

Until here, the feature extraction process is completed, which is a crucial part to detect face in an image and acquire the face images that are found. Generally speaking, this algorithm is implemented using MATLAB and tested for more than hundred images. This algorithm detects not only one face at a time but also multiple faces within an image. Small amount of oriented face is acceptable. The results are mostly satisfactory for all purpose.

2.7 Face Recognition Method

The facial recognition algorithm is a method of building a biometric face model for further analysis and the face recognition process. The goal of this step depends on what the facial recognition software is used for — surveillance or authentication. This step should ideally produce a 1:1 match for the subject. This may be done in multiple ways, a quick pass to narrow down the options, then enable the more complex layers to take over. As mentioned earlier in Chapter 2.5, the face detected in an image will be then analyzed and converted to a series of numerical code, also known as faceprint. At the end, the goal of a facial recognition system is to be able to recognize a person face to grant access or to identify their identity. Thus, your code is then compared against a database of other faceprints. This database has photos with identification that can be compared. The technology then identifies a match for your exact features in the provided database. It returns with the match and attached information such as name and address.

Some companies analyze skin texture along with facial recognition algorithms to increase accuracy. Support Vector Machine (SVM), Local Binary Patterns and 3D Recognition are one of the most common face recognition methods that would be discussed based on the researches regarding their unique characteristics and how the process works. However, there are other face recognition methods that have been discovered such as Fisherfaces, Facenet, Megvii (FACE++) and so on. Fisherfaces is one of the most popular facial recognition algorithms; it's considered superior to many of its alternatives. As an improvement to the Eigenfaces algorithm, it's often compared to Eigenfaces and considered more successful in class distinction in the training process. The key advantage of this algorithm is its ability to interpolate and extrapolate over lighting and facial expression variation.

2.7.1 Support vector machine (SVM)

Support vector machine (SVM) is a machine learning algorithm that uses a two-group classification principle for distinguishing faces from "not-faces". For each category, a SVM model receives a labeled training data set to categorize new test data. SVM is a learning technique that is considered an effective method for general purpose pattern recognition because of its high generalization performance without the need to add other knowledges (A. S. Tolba, 2006). Researchers apply linear (Figure 2.19) and non-linear (Figure 2.20) SVM training models for face recognition. The recent results show that the non-linear training machine has a larger margin and better recognition and classification results.

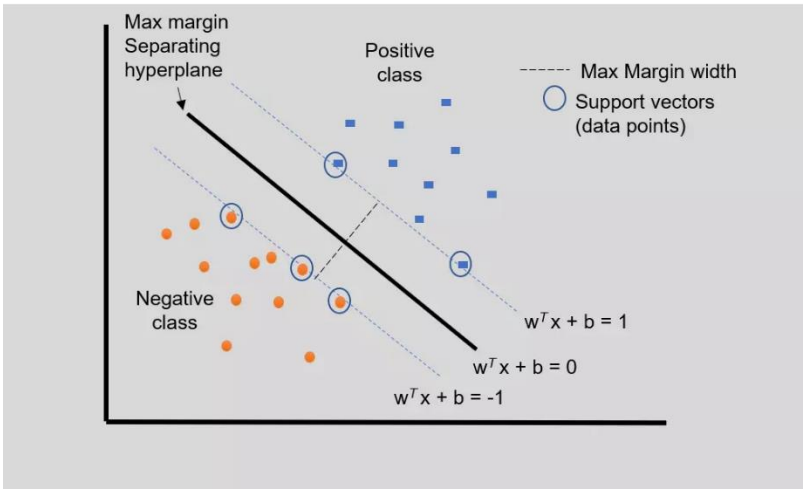


Figure 2.19: Linear SVM

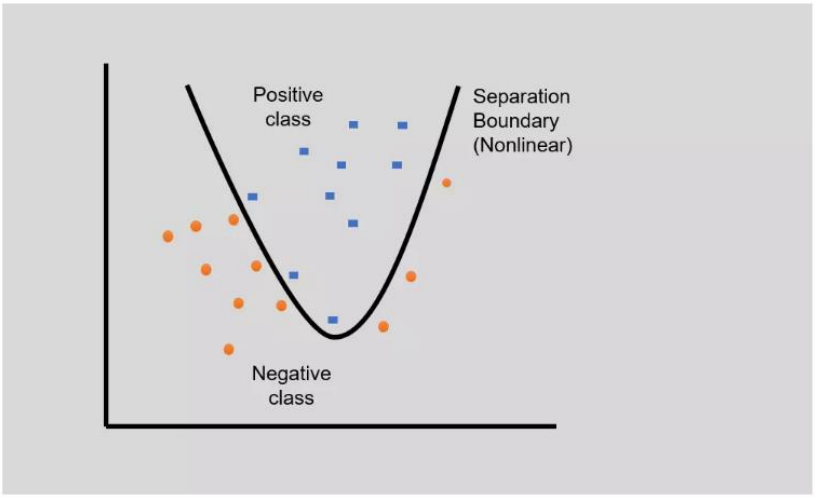


Figure 2.20: Non-linear SVM

In summary, the main characteristics of SVMs are:

1. They minimize a formally proven upper bound on the generalization error
2. They work on high-dimensional feature spaces by means of a dual formulation in terms of kernels
3. The prediction is based on hyperplanes in these feature spaces, which may correspond to quite involved classification criteria on the input data
4. That outliers in the training data set can be handled by means of soft margins.

The face recognition system for the SVM is using one-vs-all strategy. SVM is the class of maximum margin classifiers. It performs pattern recognition between two classes by finding a determine surface that has maximum distance to the closest points in the sample image with termed support vectors. For example, based on the sample image shown in Figure 2.21 (input image) and Figure 2.22 (output image) the sizes of the images have been shifted and the gray values are converted into feature vectors.

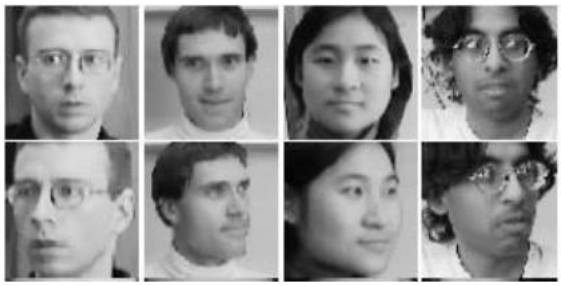


Figure 2.21: 58 x 58 pixels' sample images

Figure 2.22: 40 x 40 pixels sample images extracted by the SVM face detector.

The input image is 58 x 58 pixels whereas for the output image is only 40 x 40 pixels. The downside is that the difference between head pose leads to strong variations in the images of a person's face.

2.7.2 Local Binary Patterns

The Local Binary Patterns (LBP) proposed by Ojala et al. in 1996 has been introduced for facial recognition, as a simple, effective texture operator in computer vision. The process involves dividing the face image into independent regions where the LBP operator is implemented to codify every pixel of each region by thresholding the 3 x 3 – neighborhood of each pixel with the center pixel of each pixel value and by binarizing it which is as shown in Figure 2.23. After that, a local texture descriptor is created which includes the histogram of the codes for each and every face region. A global description of the face is then shown by concatenating the local descriptors. The LBP approach has been widely adopted for facial recognition and has been further improved such as the Local Directional Patterns (LDP).

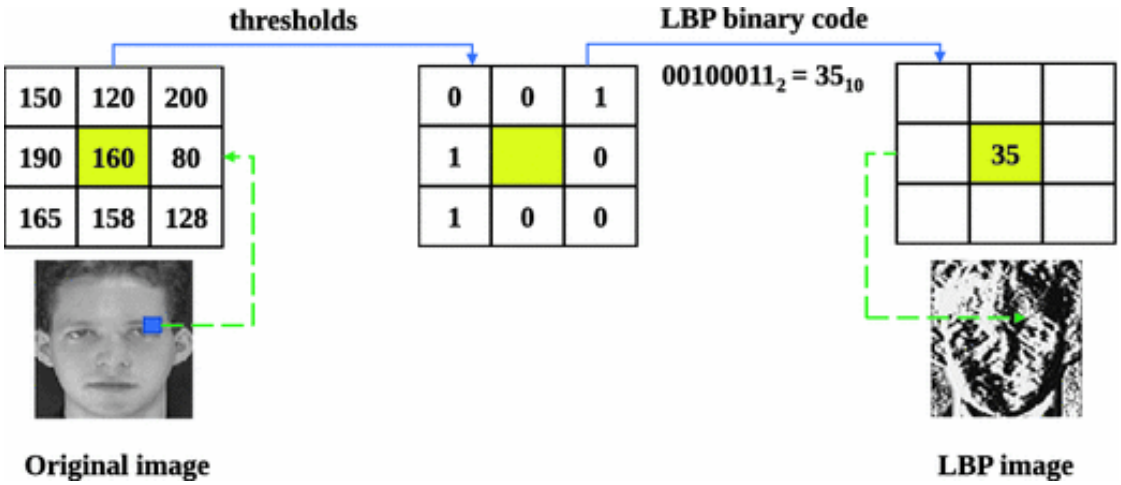


Figure 2.23: The image before and after applying LBP operator

The operator was extended to use neighborhoods of different sizes. Using circular neighborhoods and bi-linear changing the pixel values allow any radius and number of pixels in the neighborhood (Xing Yong, 2016). The notation (P, R) means P sampling points on a circle of radius of R. From the Figure 2.24, it shows the pixel values are bi-linear interpolated. The pixel values are bi-linear interpolated whenever the sampling point is not in the center of a pixel.

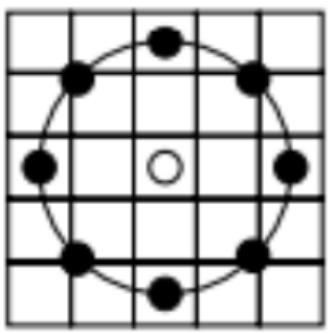


Figure 2.24: The circular (8,2) neighborhood

Local Binary Patterns Histogram (LBPH) is a method that uses local binary patterns (LBP), that marks pixels in an image by setting each pixel's neighborhood threshold and treating the result as a binary number. At the learning stage, the LBPH algorithm creates histograms for each image that is labeled and classified (Technologies, 2021). Each histogram represents each image from the training set. This way, the actual recognition process implies comparing histograms of any two images.

Entropy based LBP (ELBP) is proposed to improve the performance of feature extraction technique. The proposed work computes information content of each neighborhood pixel and, thus the calculated entropy contributes as an adaptive weight to gauge the information gained from each neighboring pixel (B. Sree Vidya, 2018). In original LBP, non-uniform patterns were not considered since these patterns increased the computational complexity of feature extraction. When applying ELBP feature extraction on to biometric images, the images are comparatively small and hence do not increase the complexity of computing non-uniform patterns. Consideration of non-uniform patterns for biometric images add more significance in extraction features as biometric images are highly unique and differ greatly from one user to another (B. Sree Vidya, 2018). The Depiction of the proposed ELBP is shown in Figure 2.25.

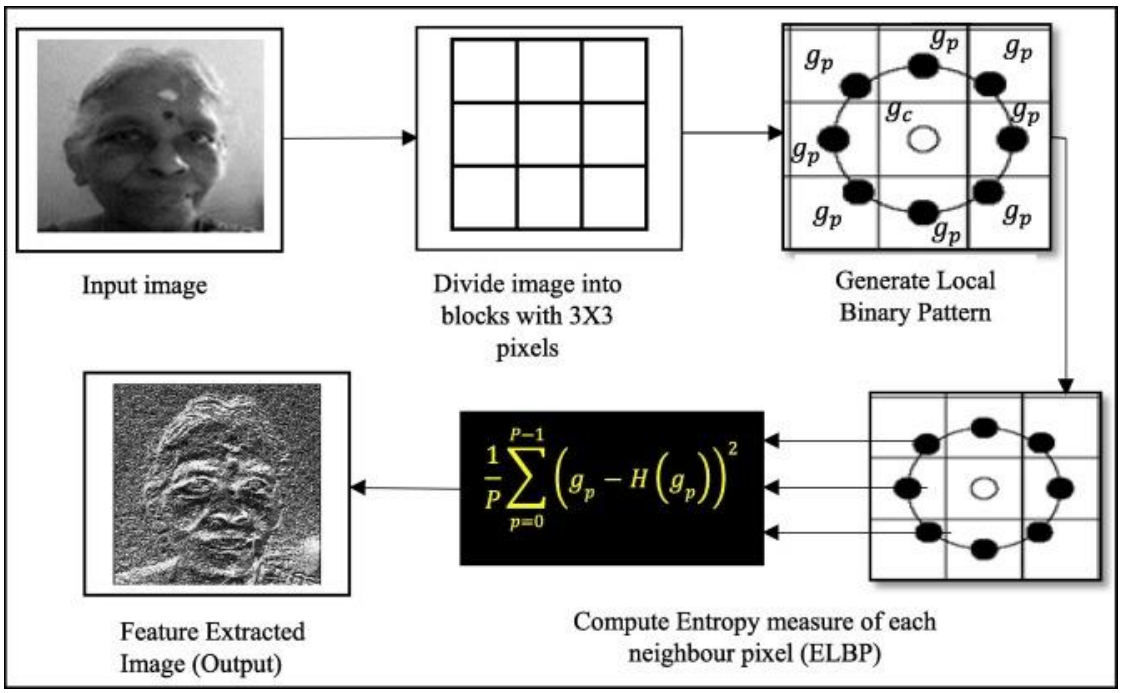


Figure 2.25: The Entropy Based Local Binary Pattern (ELBP) Depiction

2.7.3 Three-Dimensional Recognition

The underlying idea of 3D face recognition technology is based on the human skull's unique structure as each person's skull structure is special and can be described and recognized by several dozen parameters. This facial recognition method works by comparing a 3D facial scan to the database patterns. It has an essential advantage — makeup, facial hair, glasses, and similar factors don't affect the detection and recognition process (Technologies, 2021). The latest research based on Ioannis A Kakadiaris's report has used the technology of mapping the 3D geometry information on a regular 2D grid. It allows the combination of 3D data's descriptiveness with 2D data's computational efficiency and shows the highest performance reported on the FRGC v2 (Face Recognition Grand Challenge 3D facial database).

The face recognition procedure can be divided in two phases based on Ioannis's theory, enrollment and authentication. Figure 2.26 shows how the raw data are converted to metadata and stored in the database during the enrolment phase for the 3D Face Recognition system.

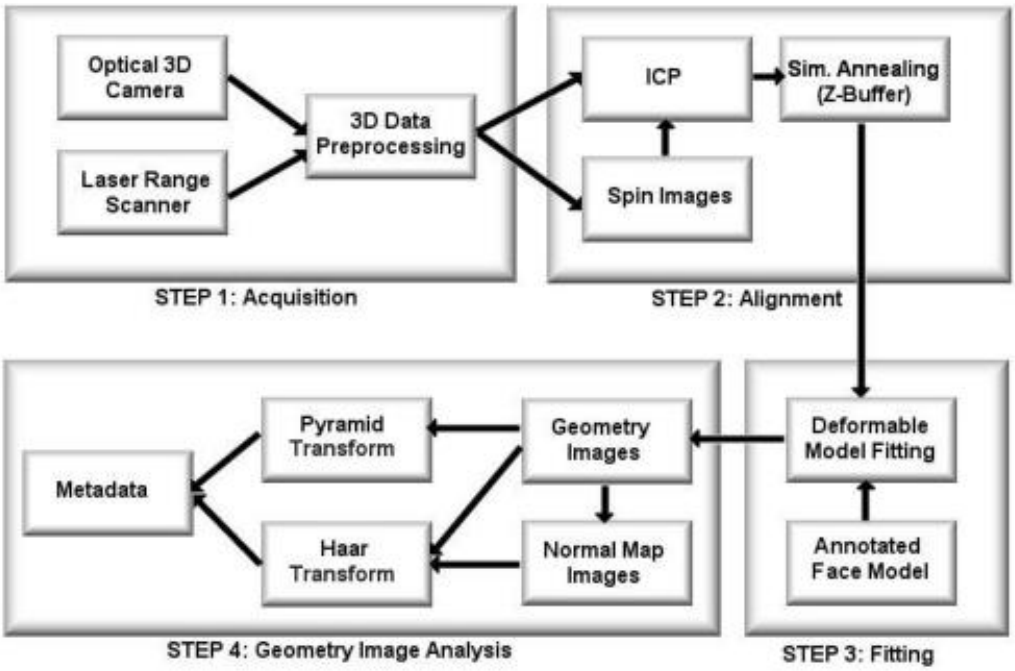


Figure 2.26: Enrollment phase of the proposed integrated 3D face recognition system

During the enrolment phase, 4 general steps will be taken place before the metadata can be stored into the system database. Firstly, the acquisition step is where the raw data are acquired from the sensor and converted to a 3D polygonal representation using the sensor-dependent

preprocessing. Next, the alignment step occurs to allow the data to be aligned into a unified coordinate system using a scheme that will combine a few different alignment algorithms to ensure the accuracy. After that, the deformable model fitting step is taken place where an annotated face model is fitted to the data. Lastly, the geometry image analysis is the step that derives a geometry and normal map from the fitted model and wavelet analysis is applied to extract a reduced set of coefficients as metadata.

After the enrolment phase is the authentication phase which involves the metadata being retrieved from the database to be directly compared using a distance metric. Ioannis introduced a novel approach under his research that utilizes and combines two different distance metrics for the two transform types (Haar and Pyramid). As mentioned earlier, the facial expressions affect the performance of many other face recognition system to an extent, however for the 3D face recognition system, the verification rate is not decreased significantly when expression are present based on the experiment carried out by Ioannis, the results are as shown in Table 2.1. An example of these facial expressions for a single individual is depicted in Figure 2.27.

Table 2.1: Performance of Ioannis's system on Full database, on a subset containing only non-neutral facial expressions, and on a subset containing only neutral expressions

	ROC I	ROC II	ROC III
Full Database	97.3%	97.2%	97.0%
Non-neutral Expression	95.6%	95.6%	95.6%
Neutral Expression	99.0%	98.7%	98.5%

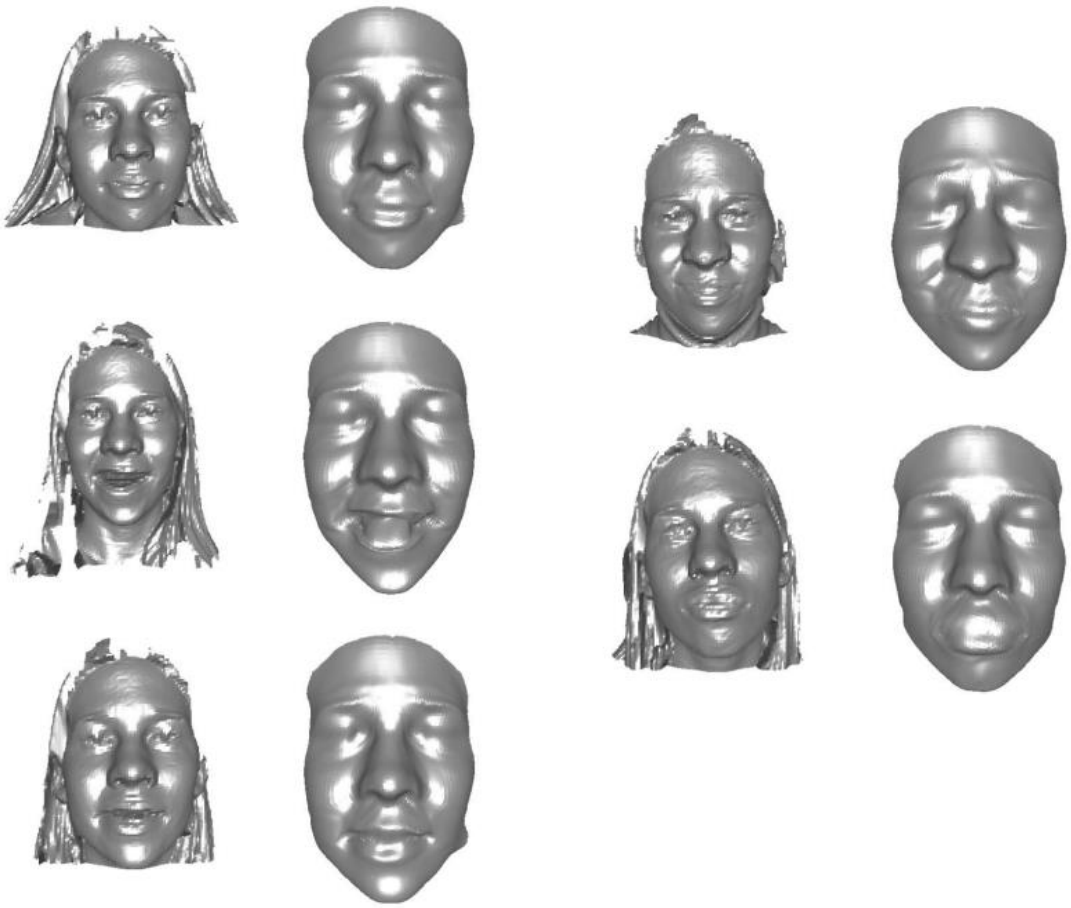


Figure 2.27: A single subject with neutral, surprise, happiness, disgust, and sadness expressions along with the corresponding fitted models

2.8 Training Database Method

Before facial recognition algorithms are ready for performing necessary tasks, they need to go through large amounts of data — precisely labeled image sets. These sets are used to develop a machine learning model. Traditional machine learning depends on shallow nets, which is the composed of one input and one output layer, and at the very most including one hidden layer in between them. When there are more than three layers (including input and output), the machine learning model is qualified as "deep" learning. To summarize, deep learning is a strictly defined, technical term that indicates a machine learning model is having more than one hidden layer.

2.8.1 Convolutional Neural Network (CNN)

Convolutional neural network (CNN) is one of the breakthroughs of artificial neural networks (ANN) and AI development. It's one of the most popular algorithms in deep learning, a type of machine learning in which a model learns to perform classification tasks directly on an image, video, text, or sound (Technologies, 2018). The model shows impressive results in several fields: computer vision, natural language processing (NLP), and the largest image classification data set (Image Net). In this case, CNN plays a significantly important role in facial recognition. CNN is a normal neural network with new layers — convolutional and pooling, not only that CNN have dozens and hundreds of these layers, and each of them learns to detect different imaging features.

In CNN, each layer of nodes trains on a distinct set of features based on the previous layer's output. As shown in Figure 2.28, the further you advance into the neural net, the more complex the features your nodes can recognize, since they aggregate and recombine features from the previous layer (Xing Yong, 2016).

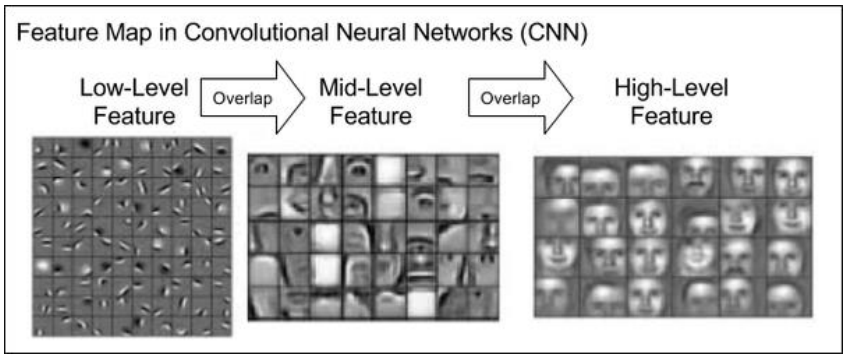


Figure 2.28: Successive model layers learn deeper intermediate representations

2.8.2 FeedForward Neural Network (FFNN)

FeedForward Neural Network (FFNN) is an artificial neural network where in connections between the nodes will not form a cycle, which makes it different from its descendant: the recurrent neural networks. The FNN was the first and simplest structure of artificial neural network devised. This type of network structure is generally used for pattern recognition applications. System network properties are: input layer has 900 inputs; hidden layer has 41 neurons and output layer has 26 neurons. Output layer has 26 neurons since the number of people in database is 26 (Cahit Gürel, 2012).

Chapter 3

Methodology and Requirements Analysis

3 Methodology and Requirements Analysis

3.1 Required Hardware and Software

3.1.1 Hardware

The hardware that will be used to develop the Facial Recognition Prototype is the Laptop IdeaPad Slim 5i Pro (14", Gen 6) (Storm Grey) from Lenovo Company. This laptop uses the 11th Generation Intel® Core™ i7-1195G7 Processor, 4 cores, 8 threads, 16GB memory as well as 512 GB of storage which is sufficient enough to code this project. The screen display is 14 inch (2240 x 1400) with anti-glare feature that could display the video clearly which consist of the human face. Another important aspect for the face recognition to perform well is the camera of the laptop. The camera uses IR&RGB with Array Microphone to maximize the ability to capture clear image of the people testing with the prototype. Other than that, a wireless mouse is used to control the laptop to progress the face recognition process without limitations.

3.1.2 Software

In order to allow the working of the Facial Recognition Prototype, the software was an important part that could be considered in before the development phase begins. Firstly, the operating system (OS) that was used for this project will be the typical Windows 11 operating system. This operating system under Microsoft Company is commonly used in relatively new released laptop that are sold starting in 2019 to simplify their user experience and design, with few more functionalities compared with its previous version, Windows 10. Laptops that are before 2019 will be unable to install the OS. The major reason for applying Windows 11 in this project is because of its simplicity, learnability, user friendly as well as the easiness to access Windows 11. A lot of different tools that are suitable to be used by developers can be easily obtained from the terminal. Although Windows 11 are less professional compared to MAC OS or Ubuntu, Linux, it is more reliable as target users are more familiar to this OS and the requirement for hardware is relatively higher than normal computer or laptop.

Furthermore, the next software to be discussed is the Visual Studio Code and Command Prompt, which is the development platform for our Facial Recognition Prototype. The Visual Studio Code is selected to be used as an editor, debugger and compiler that is easy to use for

this project. This is because Visual Studio Code is compatible with different programming language and has a smooth relaxing user interface design that makes development phase more enjoyable. Therefore, Visual Studio Code is chosen for the writing of the programming code also due to the reason that it is a very simple yet powerful platform that fits the job. On the other hand, command prompt is used when using the pip install function to add the python library for the project.

The next software to talk about is the programming language to be used in this project, which will be Python. This is mainly because a huge standard library is available in Python, making it highly flexible to be coded to satisfy the needs of development and reducing the needs for creating a new code. Python is a very common programming language today that is used by different programmers in the world. Thus, it allows easier integration between different applications. Besides that, a lot of open-source framework and tools are available for Python, while reducing the time for additional development, it also helps to minimize the required cost significantly, making the project more economical.

Based on the internet research, it is obvious that most of the facial programming uses OpenCV to code the program, such as for face detection, feature extraction as well as facial recognition process will be able to use OpenCV to develop. Through various tutorials, it is true that OpenCV is the most needed for this project as it will greatly reduce the lines of coding and ensure the simplicity of developing the Facial Recognition Prototype.

3.2 Research Planning

3.2.1 Project Flow

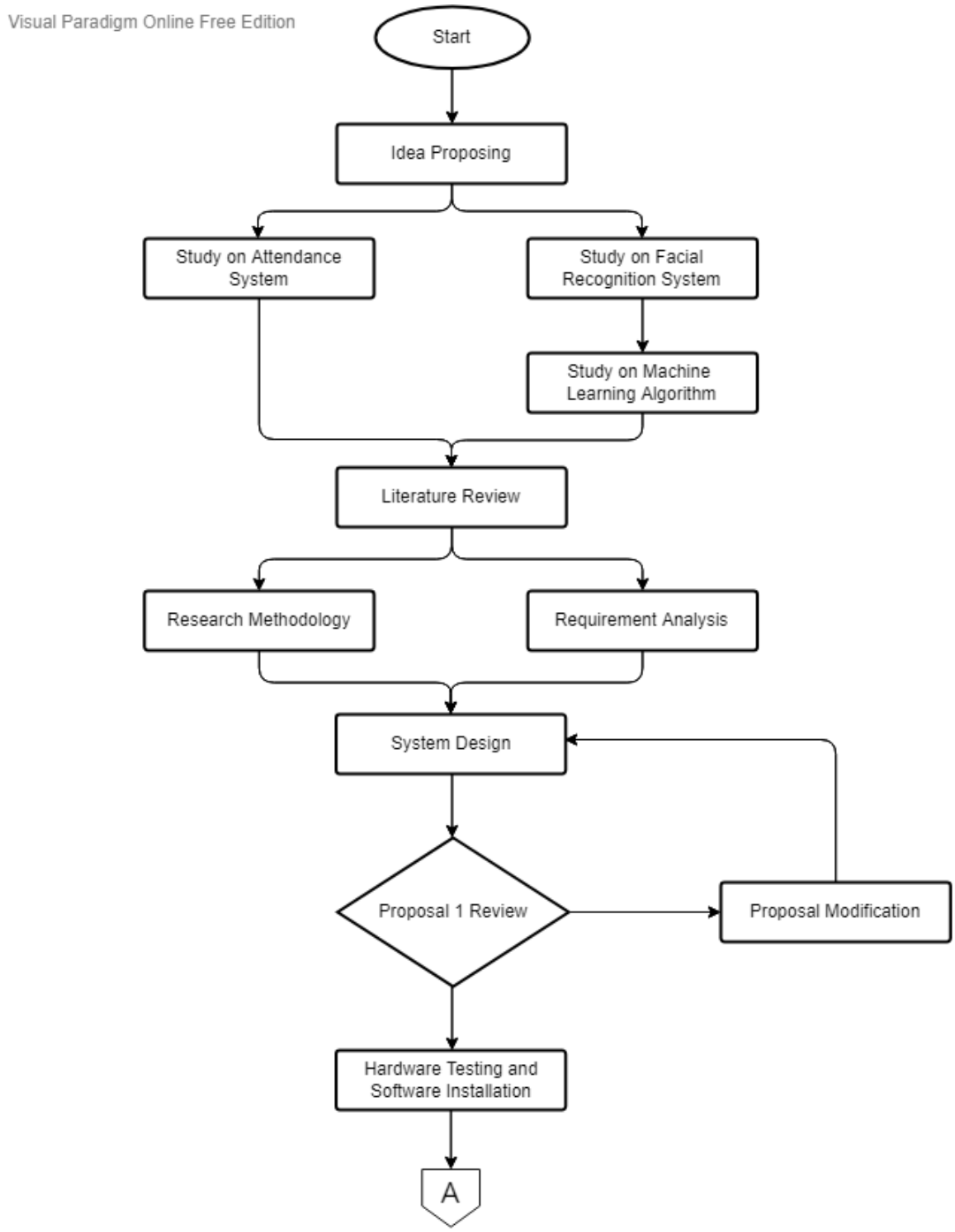


Figure 3.1 (a) Program Flow Chart (Page 1)

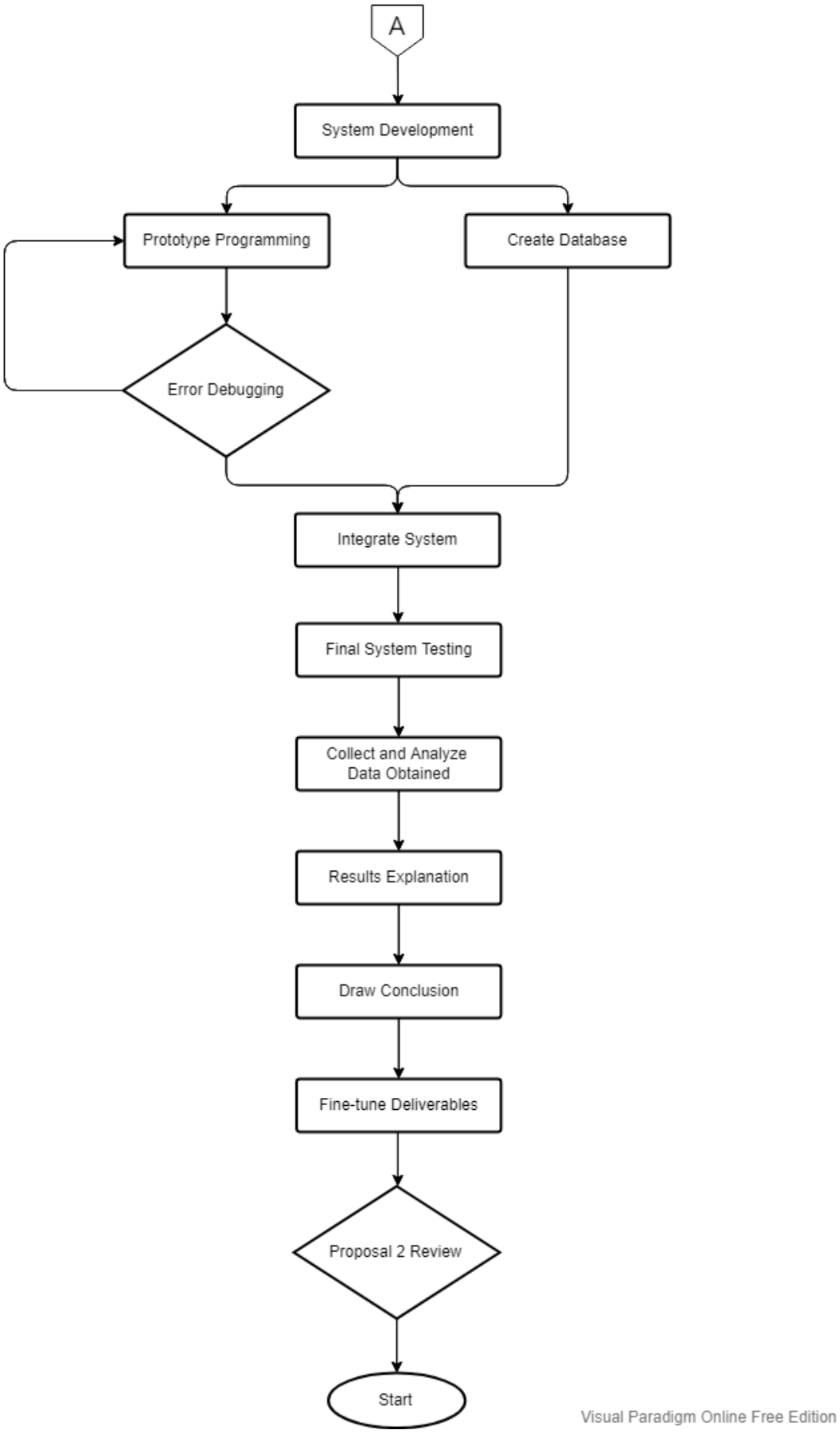


Figure 3.1 (b) Program Flow Chart (Page 2)

3.3 System Overview

3.3.1 Use Case Diagram

The Facial Recognition Prototype is proposed to be implemented in the attendance system of the local academic institutions and thus, there are 2 different users that is targeted to be handling this system which are the academic staff and students. The students are mainly focused on taking their attendance, whereas the staff are given the responsibility to view the attendance list, The overall use case diagram for the Facial Recognition Prototype are:

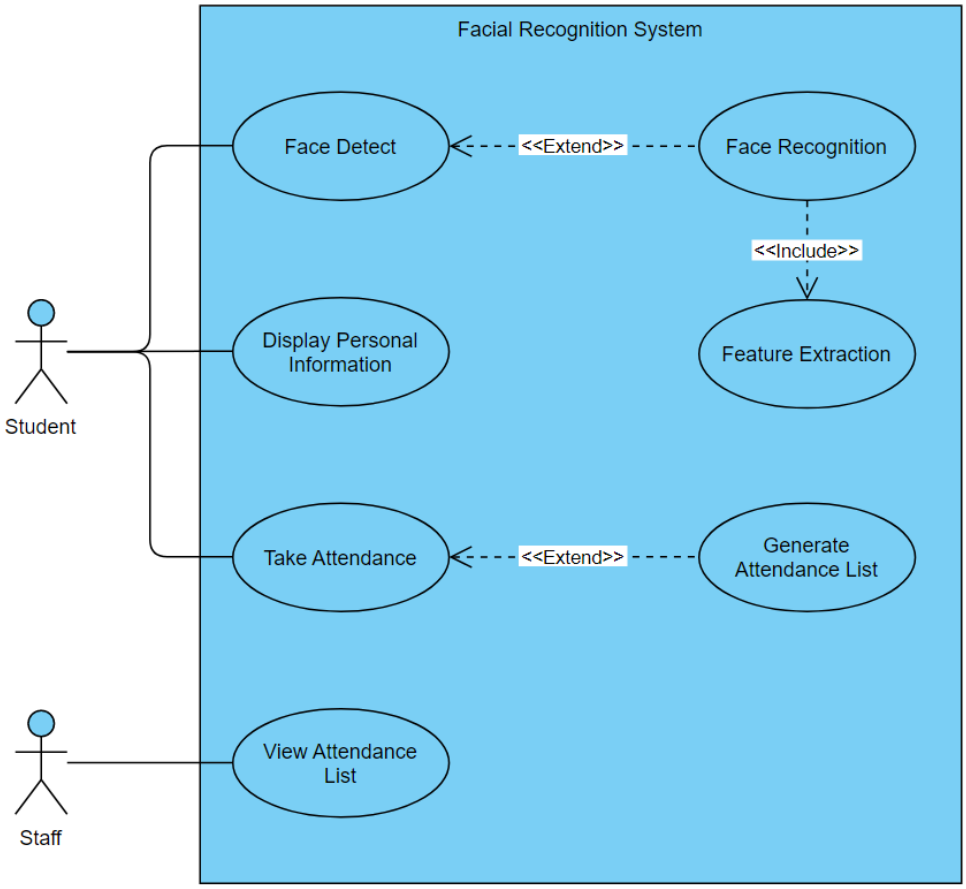


Figure 3.2: Use Case Diagram

3.3.2 Use Case Description

<table>
<tr><td colspan="2">Use Case Name: Facial Recognition</td></tr>
<tr><td colspan="2">Brief Description: The use case allows students to take attendance for their class through face recognition and identifying their identity.</td></tr>
<tr><td colspan="2">Actor: Students</td></tr>
<tr><td colspan="2">Precondition: The user is a valid existing student whose images are stored in the database</td></tr>
<tr><td colspan="2">Main Flow of Events:</td></tr>
<tr><td>Actor Action</td><td>System Response</td></tr>
<tr><td>1. Before entering the classroom, the students stand in front of the system’s camera.</td><td>2. Opens camera, detect the student’s face by showing the frame including the student’s face.
3. Extract the feature information for the facial recognition process.
4. Compares the people in front of the camera with the faces in stored database
5. Display the user personal information to validate identity.</td></tr>
<tr><td>6. Check whether the identity is validated correctly, confirm the attendance by clicking the “take attendance” button.</td><td>7. Record the student’s attendance into the attendance list.</td></tr>
<tr><td colspan="2">Alternative Flow of Events:
A1. Step 1:
If the student did not stand in front of the camera, the system will unable to detect the student face and thus the system will have no reaction.

A2. Step 4:
If the system is unable to sort out the identity of the user in front of the camera, the system will display “Unknown Person” and does not allow the user to take attendance.

A3. Step 6:
If the system displays the wrong identity which is not the student using the system, the student may click the “return to identification” button.

A4. Step 7:
If the student has already taken his or her attendance, the system shall display “Attendance already existed”.</td></tr>
<tr><td colspan="2">Post Condition: Students successfully or failed to take attendance for class.</td></tr>
</table>

3.3.3 Functional Requirements

Facial Recognition System
Roles: Students, Staff, Admin
The system shall allow the **students** to: 1. Detect their face through webcam of the computer. 2. Recognize their identity from existing database. 3. View their personal information to verify themselves 4. Take attendance for the current class. 5. Change password when necessary. 6. Train the system by importing more faceprints.
The system shall allow the **staff** to: 1. View the staff profile. 2. Change password when necessary. 3. View attendance list. 4. Mark attendance for student. 5. Generate attendance code for all students.
The system shall allow the **admin** to: 1. Register new member for the system (student / staff). 2. View member's records. 3. Update member's personal information. 4. Delete member when necessary.

3.3.4 Non-functional Requirements

As a Facial Recognition System to be implement in university's attendance taking system, there are some non-functional requirements that should be focused in order to have a high-quality application which will satisfy the users. The non-functional requirements are analyzed and listed below.

Performance Requirement

A Facial Recognition System should be able to perform the functions that it is required to help users to complete their tasks and reach their goals. The system shall be able to perform with a response time of at most 5 milliseconds per request. Not only that, the system should load and be usable within 3 seconds. This also means that the system must be efficient while effective. Most importantly, the system should be able to update the attendance list on real time. The system is expected to be able to recognize and store as many students as possible in the database.

Reliability Requirement

A Facial Recognition System should possess with high reliability, in which the reliability requirements refer to how often a system fails and how accurate the system is. Therefore, the system's downtime shall be less than 0.05% weekly (8.4 hours) excluding maintenance time. The availability of the system is important as if the system is easily inaccessible, the system will be unable to gain user trust and satisfaction. Other than that, the accuracy of the process of recognizing student's face should be high, which is at least 99% to avoid mistakes that will cause troublesome to the students and staff.

Security Requirement

A Facial Recognition System should be secure so that confidential data will not be stolen. In other words, the system should not disclose any personal information about the students and staff to other parties without authorization. Since all user's information and booking details are stored in the database, it is to be ensured that the back-end servers shall only be accessible by administrators with authorization.

Chapter 4

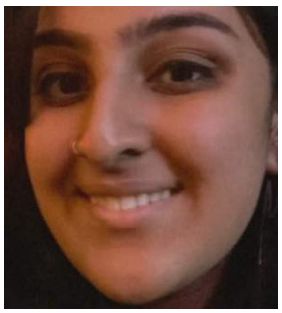
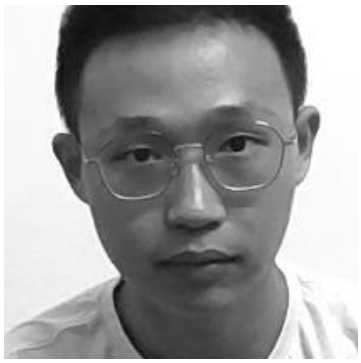
Data Collection and Design

4 Data Collection and Design

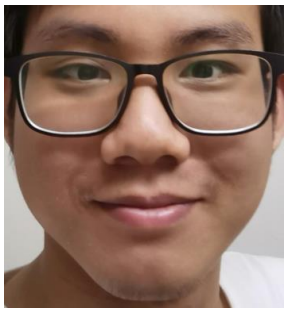
4.1 Data Collection

25 people is asked to take their photo weekly for a period of 12 weeks and collected while developing the prototype. These images will be stored in the database as dataset of the face image. In Table 4.1 lists out the 25 of the testers that helped in providing their photos of themselves as test data to be trained in the database. If the face images inside the training set is very blur, then the accuracy of the face recognition for this kind of system will be very low and the confidential ratio will also low (Xing Yong, 2016). In conclusion, the more the database has learnt, the higher the confidential ratio will be for the recognition to be successful.

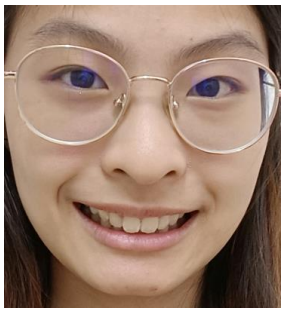
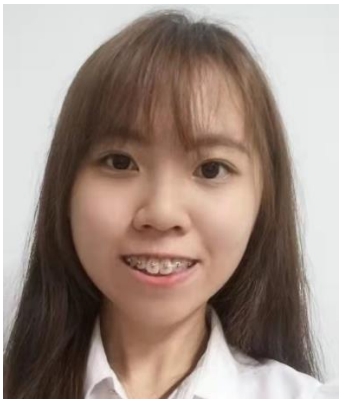
Table 4.1: 20 sets of training images which may be used to train the database of the facial recognition prototype

No.	Face Image Example	Name	Age
1		Ameeshajeet Kaur Thind	22
2		Chong En Han	22

3		Chuah Jia Xuan	21
4		Elisha Hor Zi Xuan	21
5		Foo Jia Qi	21
6		Heng Zhi Xuan	20
7		Jack Siow	21

8		Lee Quan Jin	20
9		Lee Xin Wei	22
10		Lee Xin Yun	26
11		Lee Yan Jie	21
12		Lee Ying Shan	21

13		Lim Shin Yie	21
14		Mervin Leo	21
15		Mok Yuen Yua	22
16		Seah Wei Ming	21
17		Siew Wai Han	21

18		Tan Choy Yin	21
19		Tan Yoke Shuen	22
20		Tan Zhe Yan	21
21		Tia Wan Tong	21
22		Wong Kar Lok	22

23		Yap Yong Yi	18
24		Yap Wei Xiang	21
25		Yee Jian Le	21

4.2 UI Design

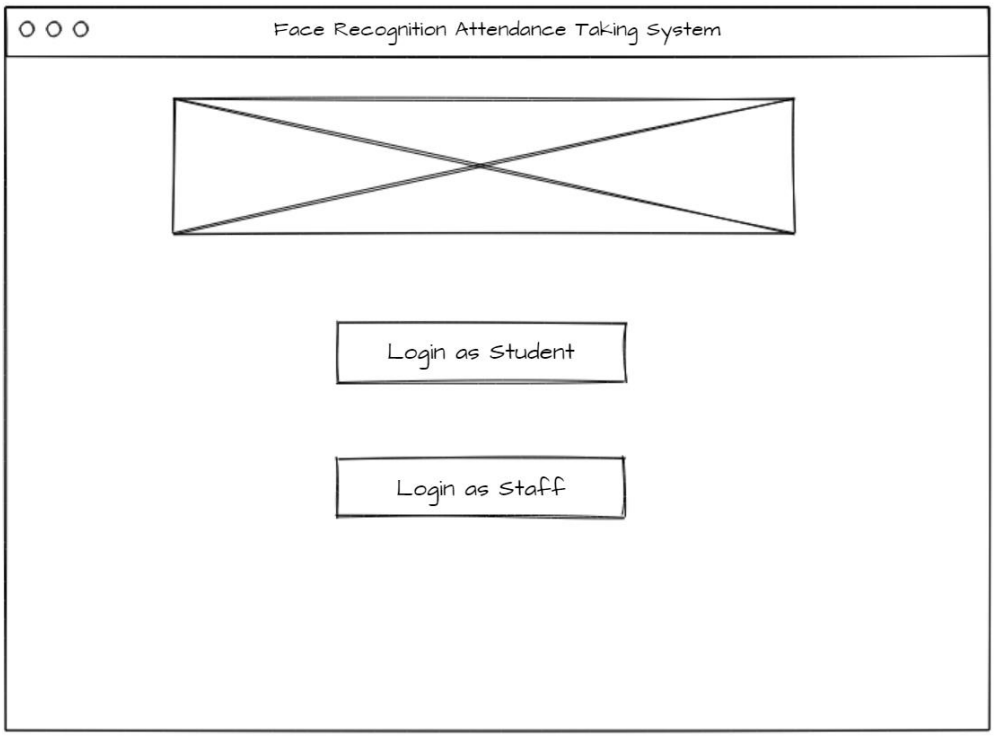


Figure 4.1: Main Menu

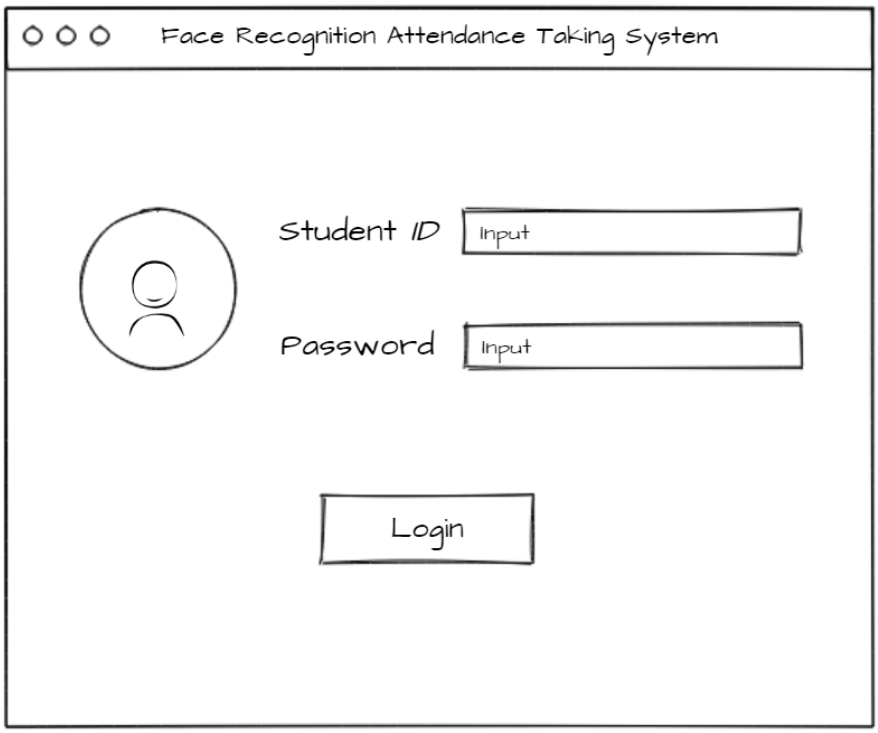


Figure 4.2: Student Login

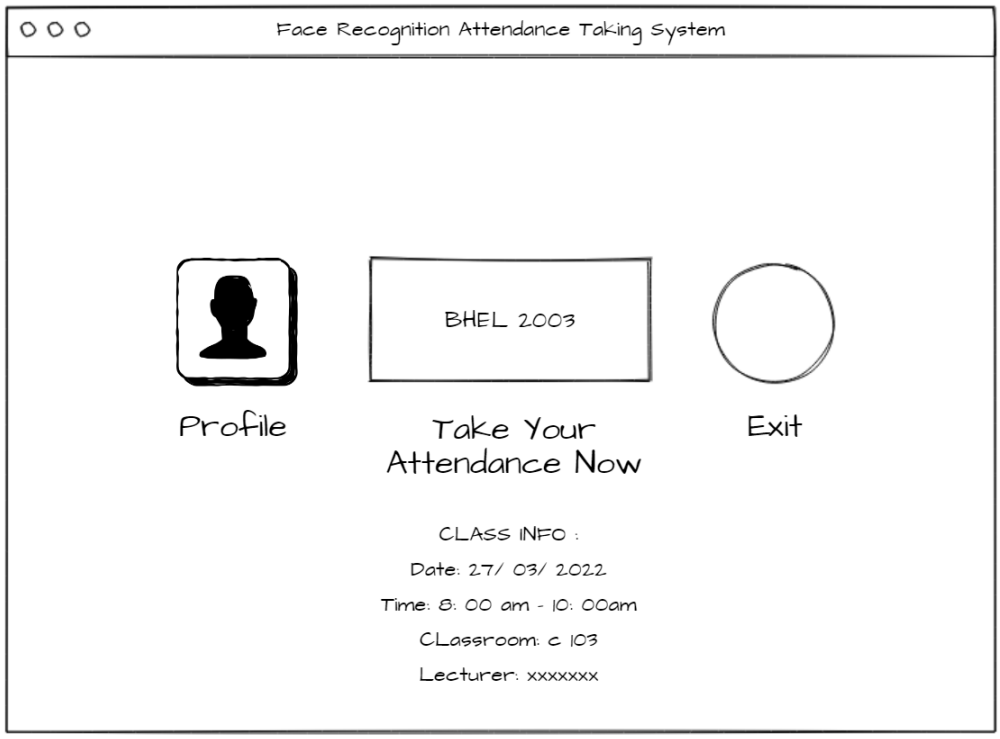


Figure 4.3: Student Homepage

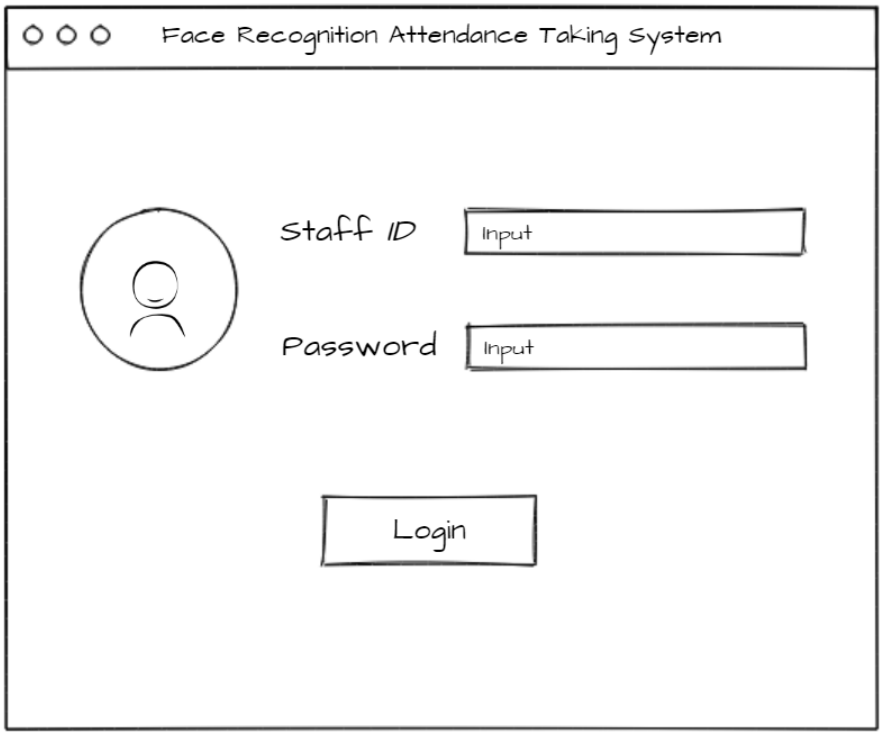


Figure 4.4: Staff Login

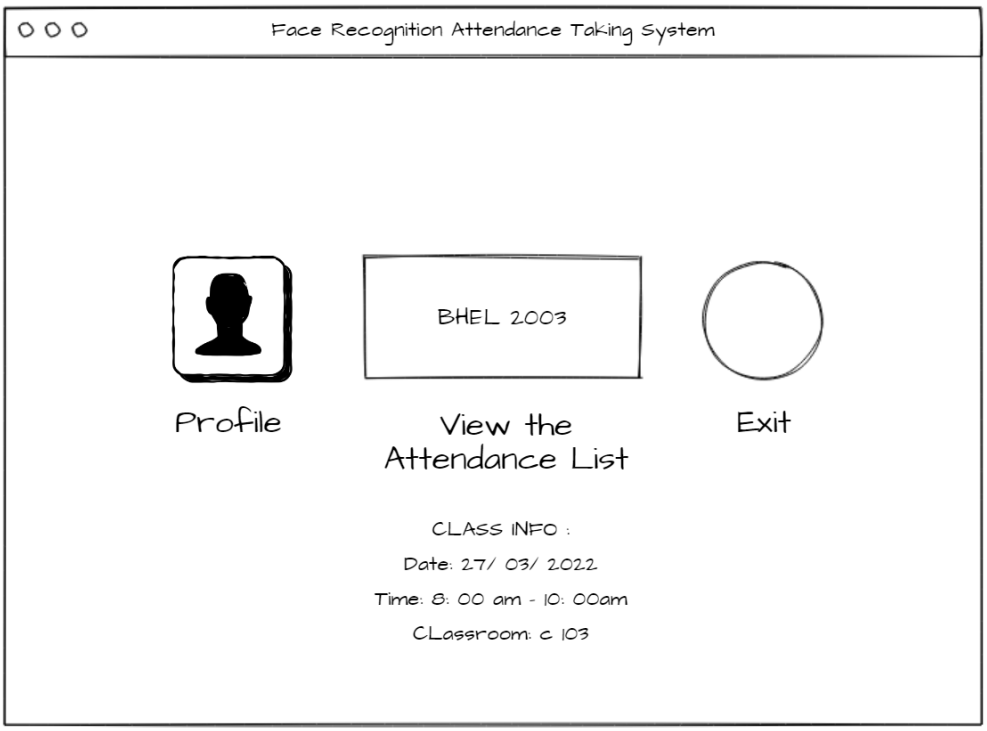


Figure 4.5: Staff Homepage

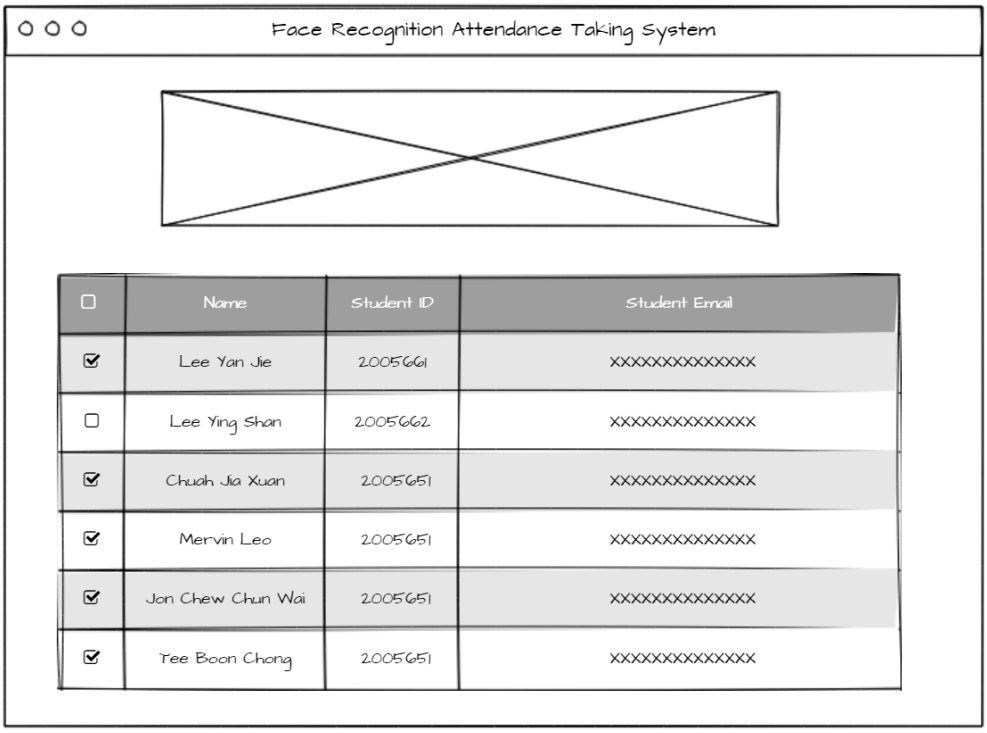


Figure 4.6: View Attendance List

4.3 Data Design

4.3.1 ERD Diagram

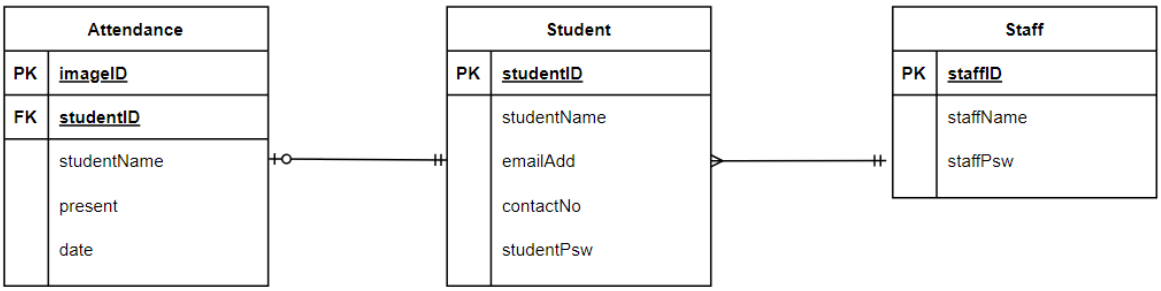


Figure 4.7: The ERD Diagram for the Facial Recognition Prototype

4.3.2 Class Diagram

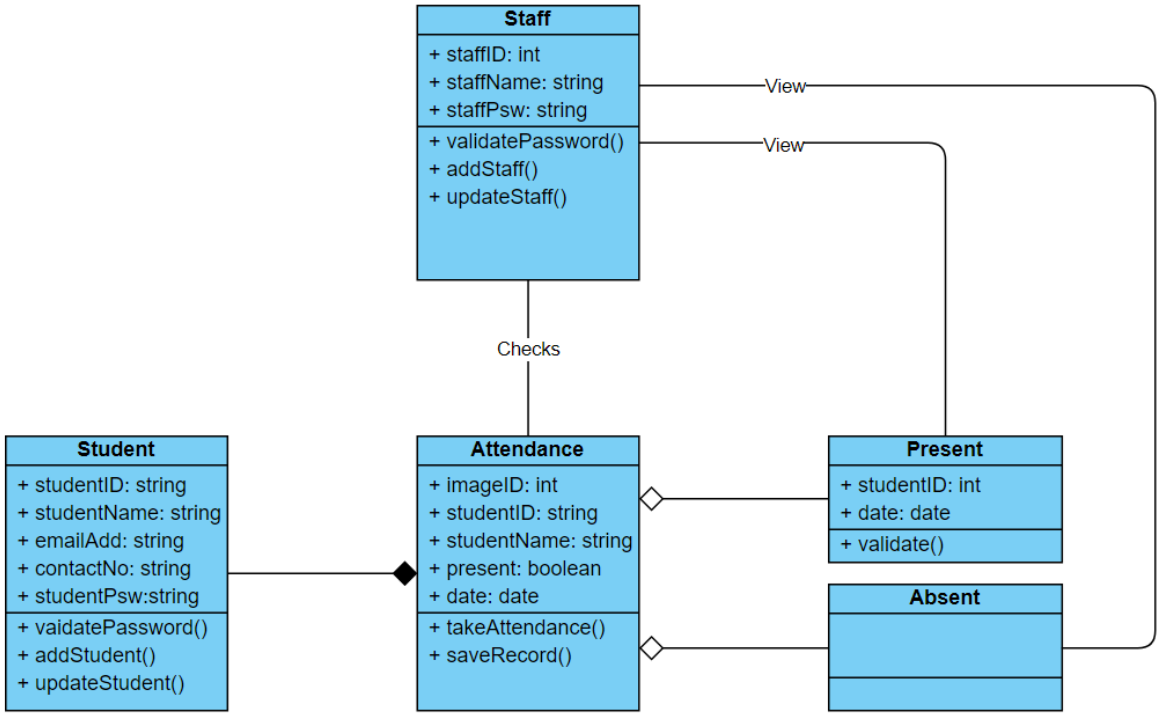


Figure 4.8: Overall Class Diagram for the Facial Recognition Prototype

4.4 Software Architecture Design

4.4.1 Sequence Diagram

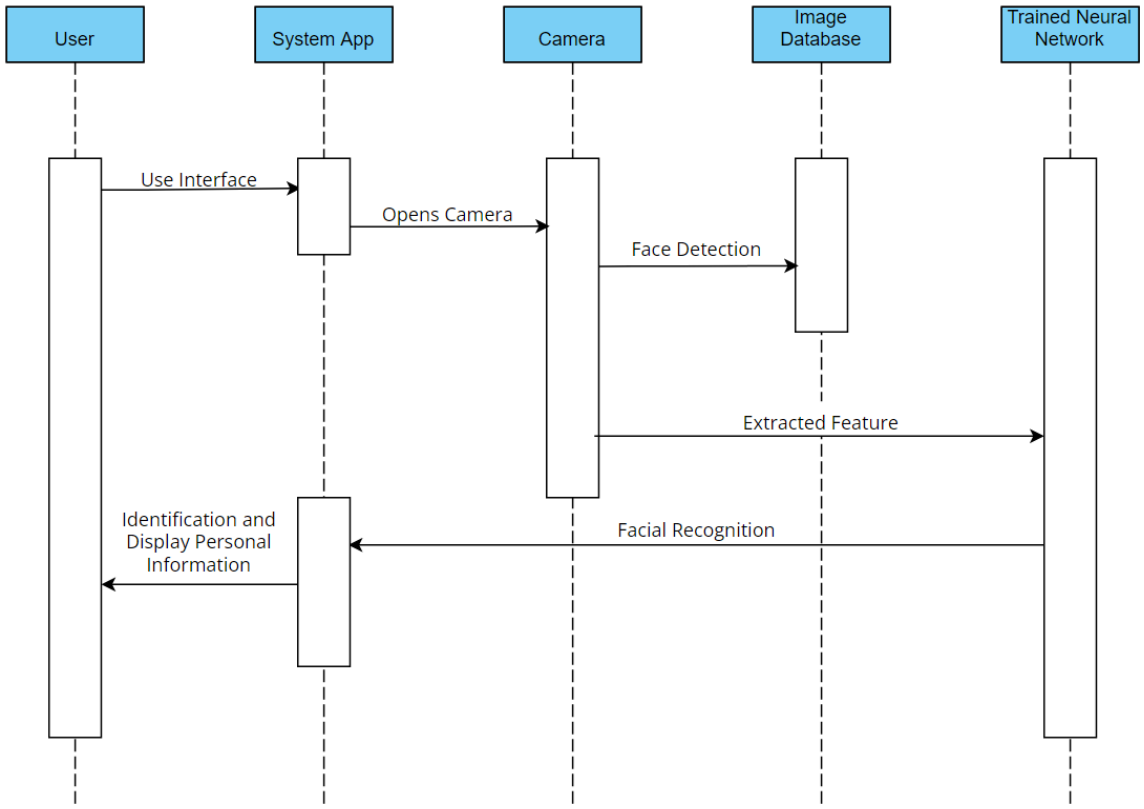


Figure 4.9: Sequence Diagram for the Facial Recognition Prototype

4.5 Algorithm Design

4.5.1 Haar Cascade Classifier

The algorithm that would be used for face detection of this prototype is the Haar Cascade Classifier. As mentioned earlier, the Haar Cascade Classifier is an object detection method used to locate objects on images. The algorithm learns from a large number of positive and negative samples. As the camera is driven by OpenCV, the cascades are brought into the prototype after this. Firstly, to implement this algorithm, through the command prompt we shall locate the root file of CV2. Using the actual file finder, we search for data folder and copy it to our project folder, named as Cascades to have the actual library with the trained database. The Haar Cascade is used for face detection, but the weakness of the Haar cascade was the facial features is only detectable in gray scales based on the documentation I have read. Thus, the camera frame that captures the image will have to convert the image to gray as shown in Figure 4.10. Again, Haar Cascade Classifier uses the change in contrast values between adjacent rectangular groups of pixels. By tuning the value of the *scaleFactor* in the code will actually increase the accuracy of the detection process, however if it goes too high, it could potentially be a problem as well. Lastly, to show what Haar Cascade has detected, in other words the region of interest, we should add a rectangle box that crops the face out only to proceed to the face recognition procedure.

Figure 4.10: Haar Cascade Classifier Face Detection tested on Lee Yan Jie

Chapter 5

Implementation and Testing

5 Implementation and Testing

This chapter will be including various implementation that has been carried out and how the prototype has been tested in terms of functionality and non-functionality. The testing aspects that will be covered for the Facial Recognition based Attendance Taking System includes the testing strategy or approach that is applied to the system, test data requirements and test environment requirements, metrics to be collected, and lastly test plan as well as test cases to verify whether or not the prototype is able to function correctly as expected.

5.1 Implementation / Coding

The implementation of a system refers to the process of installing hardware and software, as well as the expected operating environment. As mentioned earlier, the software that has been utilized for this prototype is Visual Studio Code running on Windows 11 operating system.

5.1.1 Libraries Installation

1. **import cv2**

   OpenCV-Python is a library of Python bindings designed to solve computer vision problems. For example, *cv2.imread()* method loads an image from the specified file, which is one of the functions used in the Facial Recognition based Attendance System where the program reads the faceprints and store it into the database. Not only that, the function is also used to scan student's face in real-time to take their attendance. This library can be installed through command prompt and imported to Visual Studio Code as shown in the figure below.

```
C:\Users\kathe> cd Desktop

C:\Users\kathe\Desktop> cd FYP

C:\Users\kathe\Desktop\FYP> cd Project

C:\Users\kathe\Desktop\FYP\Project> .\env\Scripts\activate

(env) C:\Users\kathe\Desktop\FYP\Project> pip install opencv-contrib-python --upgrade
Collecting opencv-contrib-python
  Using cached opencv_contrib_python-4.5.5.64-cp36-abi3-win_amd64.whl (42.2 MB)
Collecting numpy>=1.19.3
  Using cached numpy-1.22.3-cp310-cp310-win_amd64.whl (14.7 MB)
Installing collected packages: numpy, opencv-contrib-python
Successfully installed numpy-1.22.3 opencv-contrib-python-4.5.5.64
```

Figure 5.1: Installation of Open CV using command prompt

2. import os

According to GeeksforGeeks in 2022, the OS module in Python provides functions for interacting with the operating system. OS comes under Python's standard utility modules. This module provides a portable way of using operating system-dependent functionality. The *os* and *os.path* modules include many functions to interact with the file system. For example, based on figure 5.2, *os.chdir()* method is used to change the current working directory (CWD), which is the folder where the Python is currently operating. Many other methods are included in the Attendance Taking System, such as *os.mkdir()* to create a directory, *os.rmdir()* to remove a directory, *os.lisdir()* to list out files and directories, *os.rename()* to rename files as well as *os.path.exists()* to check whether a file exists which has been used in if else statements.

```
try:
    cur.execute("SELECT * FROM record")
    records = cur.fetchall()
    for record in records:
        if id == record[1]:
            file = str(record[1])

    directory = r'C:\\Users\\kathe\Desktop\\FYP\\LeeYanJie\\FYP2\\Images'
    os.chdir(directory)

    for i in os.listdir(file):
        os.remove(os.path.join(file, i))
    os.rmdir(file)

except:
    messagebox.showerror('Opps', 'Image file not found')

directory = r'C:\\Users\\kathe\\Desktop\\FYP\\LeeYanJie'
os.chdir(directory)

cur.execute("DELETE FROM record WHERE studentID = " + str(id))
con.commit()
```

Figure 5.2: Implementation of the os module in the deleteRecord() function

3. import tkinter

Tkinter is the de facto way in Python to create Graphical User Interfaces (GUIs) and is included in all standard Python Distributions. It is also the only framework that is built into the Python standard library, well known for its easy to learn widgets to create GUI elements in a simple way. The Tk widgets can help in constructing buttons, menus, data fields, scrollbar, etc. These graphical elements can also be associated with or interact with different features or functionalities, such as changing the appearance of a button widget or to allow the button widget to accept mouse clicks as well as to execute actions afterward.

4. from PIL import image, imageTK

In Tkinter, in order to load images from user system to the Tkinter window, the PIL module is needed for the program to select the required file from any directory to be displayed. Therefore, at first, we must install libraries through the command prompt, by using the command *pip install pillow* and then able to import the module. Now we may use the Image, as well as the Image TK function to perform task relevant in manipulating the images for the system, such as importing image from the directory, to resize the image while keeping the image in ratio, and so much more. This is a crucial method for the system as it highly reuses the images stored in database.

```
if os.path.isfile(img_item):
    img2 = Image.open(img_item)
    img2.thumbnail((180, 180), Image.ANTIALIAS)
    img2.save("resized_" + img_item, optimize = True, quality = 100)

else:
    directory = r'C:\\Users\\kathe\Desktop\\FYP\\LeeYanJie\\FYP2\\UI-Images'
    os.chdir(directory)
    img_item = 'user_img.png'
    img2 = Image.open(img_item)
    img2.thumbnail((180, 180), Image.ANTIALIAS)
    img2.save("resized_" + img_item, optimize = True, quality = 100)

img2 = Image.open("resized_" + img_item)
img2 = ImageTk.PhotoImage(img2, Image.ANTIALIAS)
profile_pic = Label(profile, image = img2, borderwidth = 0)
profile_pic.place(x = 250, y = 80, anchor = "n")
```

Figure 5.3: Implementation of the Image, ImageTK function from the PIL module

5. import sqlite3

As mentioned earlier about databases, all the user information as well as the attendance record is stored in the database created by SQLite3. SQLite 3 is a C library that provides a lightweight disk-based database that does not require a separate sever process and allows accessing the database using a nonstandard variant of the SQL query language. The good thing about SQLite is that it is possible to port the code from a prototype application, such as the Facial Recognition based Attendance Taking System to a larger database, for instance the PostgreSQL or Oracle, in the upcoming future to improve scalability. For example in figure 5.4, the command to be executed from the database is within the *cur.execute()* function, which means to select the last piece of information from the record. This is important to check whether or not the user already exist, to compare the user password for login validation, to keep track of student's attendance and so much more. That is why, when creating a database, identifying the primary key should be cautious to avoid duplicate of data.

```
if number == 1:
    con = sqlite3.connect('studentdata.db')
    cur = con.cursor()
    cur.execute("SELECT * FROM record ORDER BY StudentID DESC LIMIT 1")
elif number == 2:
    con = sqlite3.connect('staffdata.db')
    cur = con.cursor()
    cur.execute("SELECT * FROM record ORDER BY StaffID DESC LIMIT 1")
elif number == 3:
    con = sqlite3.connect('admindata.db')
    cur = con.cursor()
    cur.execute("SELECT * FROM record ORDER BY AdminID DESC LIMIT 1")

records = cur.fetchone()
count = 0
```

Figure 5.4: Using if-else statements to decide which database record to be used

6. import smtplib

Lastly, the smtplib module defines an SMTP client session object that can be used to send mail to any internet machine with an SMTP or ESMTP listener daemon. In order word, this module is used to assist the Attendance Taking System to send emails to the users when they have forgotten their student password, which is useful to identify their true identity and at the same time verify the request of changing the user password before actually performing any actions. However, this method is not recommended in the future as it has potential of becoming a loophole for unauthorized parties to misuse the email in sending phishing emails. Although, google has strengthen the security by using one-time use password generated specifically, it is still dangerous and less convenience for both the staff and the user.

```
check = True
sender_email = "katherine.lee0356@gmail.com"
sender_password = "wsfpoihmjtogkdnz"
receiver_email = str(user_email.get())
subject = "Digit Code to Reset Your TARUC " + user_type + " Password"
main_message = "Your Digit Code is <" + str(digit_code) + ">. Please Verify " + user_type + " Identity to
Set a New Password. "

Body = """
    From: Katherine <%s>
    To: <%s>
    Subject: %s

    %s
""" %(sender_email, receiver_email, subject, main_message)

try:
    server = smtplib.SMTP('smtp.gmail.com', 587)
    server.starttls()
    server.login(sender_email, sender_password)
    server.sendmail(sender_email, receiver_email, Body)

    messagebox.showinfo(
    'Validate Status', 'Identity Verified Successfully! \n\nA 6 Digit Code has been sent to <' + user_email.
    get() + '> !')

except (smtplib.SMTPException, ConnectionRefusedError, OSError):
    return

finally:
    server.quit()
```

Figure 5.5: Implementation of the smtplib function to send emails to user

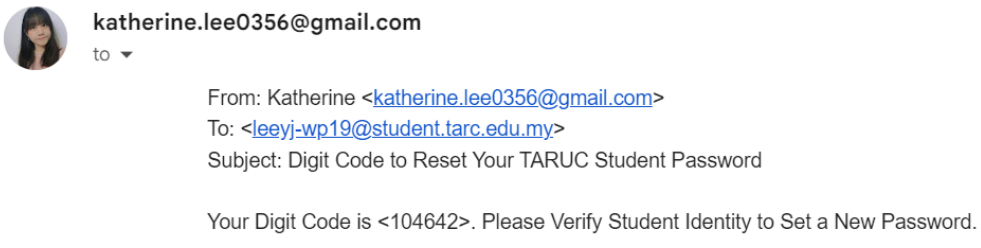


Figure 5.6: Output of the smtplib function for password recovery

5.2 Test Plan

The objective of preparing the test plan is to provide the information and framework required to plan and execute all the test processes that are necessary in order to test the system in many different aspects. A total of 35 test cases will be carried out to ensure that the system is able to function properly without errors such as logic error, syntax error, run-time error, human error and etc. However, the number of test case is less due to the reason that this project is developing a prototype-based system, thus it consists less functionality when compared with complete application system. Other than that, testing is crucial to find out the defects of the system so that the developers can fix bugs before implementing the prototype into actual software application for further development and future deployment to the society. By having a proper test plan, the developers can ensure that the Facial Recognition Attendance Taking System is operating in an error-free environment.

5.2.1 Test Scope

The testing scope for this project will cover the basic aspects of the Facial Recognition based Attendance Taking System, which includes functionality and non-functionality testing. For this project, there will be majorly 4 modules covered and all of the functionalities of each module will be tested. The modules that will be tested in this documentation are the followings as shown below:

1. Account Management Module
2. Admin Module
3. Staff Module
4. Attendance Taking Module

5.2.2 Test Approach

In order to perform testing for this Facial Recognition based Attendance Taking System, test strategy is crucial in order to assure the system quality, through a series of systematic approach for the software testing process. In this project, the following test methodologies were used:

1. **Unit Testing**

   Unit testing is the process of testing a unit which is also known as the smallest piece of code that can be logically isolated in a system. For example, in this Attendance Taking System, the user registration, update user information, login as well as take attendance are instances of such units that provides functionality and can be tested individually to see whether they work properly.

2. **Integration Testing**

   Integration testing is a type of testing where software modules are integrated logically and tested as a group to expose defects in the interaction between these software modules when they are being integrated (Thomas, 2022). For the Facial Recognition based Attendance Taking System, integration testing was carried out from time to time to ensure the project is functioning well.

3. **User Acceptance Testing**

   User acceptance testing is carried out at the final stage of the development life cycle where actual users are asked to test the software to see whether it is functioning as intended and adhere to the users' requirements or the business rules in real-world situations (Eyal, n.d.). The prototype for this project will also carry out User Acceptance Testing where a small group of students from TARUC were selected to participate, their feedbacks will then be gathered, documented for future improvements.

4. System Testing

System testing is carried out when the project is complete and fully integrated so that the developers can evaluate the system thoroughly. System testing covers several aspects of the system's capabilities to be validated such as:

a. Functional Testing

Functional testing is carried out to confirm that the features and functionalities of the prototype are working well as what the developers are expecting based on the specified user requirements as stated in the functional requirements.

b. Performance Testing

Performance testing is carried out to ensure that the system's performance is in optimal condition where all user needs are completed in the best possible way, efficiently, effectively, accurately and always stable.

c. Reliability Testing

Reliability testing is carried out to validate the precision, the extent to which measurement occurs without error, as well as the measure of stability and consistency of the system performance, so that the system is trustworthy to the user.

d. Load Testing

Load testing is carried out to determine XXX. This is important because the school needs to be aware of the quantity of users and the system needs to be prepared to accommodate the large number of students in TARUC.

e. Recovery Testing

Recovery testing is carried out as the activity of testing how well an application is able to recover from crashes, hardware failures, and other similar problems without much affecting the user experiences.

5.2.3 Test Completion Criteria

Entry Criteria

To determine whether the system is ready for testing, each of the following listed criteria must be met:

- The modules subject to be tested has been fully developed
- All the test cases are designed and prepared for each module
- All necessary testing tools, hardware, software equipment is available in order to conduct the testing

Exit Criteria

The testing is considered to be completed when the following criteria are met:

- All test cases are executed at least once
- At least 95% of all test cases have passed / partially passed
- No showstoppers or critical defects are present

5.2.4 Metrics to be Collected

Table shown below is the metrics to be collected during the testing process:

Table 5.1: Metrics to be collected

No.	Testing Metrics	Result
1	Number of modules	4
2	Number of testers	1
3	Number of test cases prepared	Account Management = 10 Admin = 9 Staff = 7 Attendance Taking = 9
4	Number of passed test cases	Account Management = 10 Admin = 7 Staff = 7 Attendance Taking = 7
5	Number of failed test cases	Account Management = 0 Admin = 2 Staff = 0 Attendance Taking = 2
6	Percentage of passed test cases	88.57%

5.2.5 Test Data Requirements

Test data in software testing is the input given to a software program during test execution. It is used to verify that the system produces the expected results for the correct inputs and also to evaluate the system's ability to handle exception or unexpected inputs (Hamilton, 2021). Table 5.2 shows the classification of test data that are existing in the prototype, with detailed descriptions and examples of which input data falls into each category. The test data is crucial as it is able to ensure that the system can achieve the results as what developers has expected. All the test data is inputted dynamically into the Attendance Taking System and are shown in the tables below:

Table 5.2: Test Data Classification

Category	Description
Text	Plain texts are mostly used throughout the system. Using the keyboard of the laptop provided, user may input any possible characters including from A to Z, numbers from 0 to 9, and special characters. For example, user name, user gender, email address and passwords are the ones that commonly used for this category.
Numbers	Certain input fields have restriction in nature that only required digit input. Thus, when the user input is not integer value, exceptions may be thrown, most of the time these data are generated by the system itself. For example, user ID, contact number as well as attendance code.
Images	Images are required when uploading an image to the profile, as well as importing images for the deep machine learning process used in facial recognition. Examples of supported image formats include JPEG, JPG and PNG. These images are used as profile picture, capturing real-time data, as well as training image.
Boolean	For the student attendance, it is categorized under Boolean as there is only two possible conditions, which is either the student attend the class (true), or is absent from the class (false).

5.2.6 Test Environment Requirements

The system testing will be executed on a Windows 11 Operating System Laptop, under virtual environment created by Python. The system is run by Visual Studio Code which does not require browsers or internet access to use the attendance taking system. In terms of the hardware criteria, any computer with a functional keyboard and a mouse is necessary in order to use the Attendance Taking System for the testing process. The recommended base system requirements are as shown in the table below to ensure a stable performance of the system:

Table 5.3: Recommended system requirements

Components	Requirements
Processor	Desktop or laptop with Intel i5 generation, 4 cores CPU @ 2.80 GHz or higher
Memory	8GB of RAM or higher
Storage	15GB or higher available disk space

In addition, the surrounding is expected to have at least one light source to provide lighting for facial detection to progress smoothly. Finally, a valid email address is also needed to be able to check the sending email function when user forgets their password.

5.3 Test Cases

A test case is a series of actions which are carried out in order to ensure that a certain feature, functionality of the system is working fine and that all user requirements are fulfilled successfully. The test case includes a set of test procedures, test data, preconditions and postconditions that are designed for a given test scenario in order to validate the requirements defined in the software requirement specifications (SRS). Thus, all the test cases related to the Facial Recognition based Attendance Taking System are portrayed as shown below.

5.3.1 Account Management Module Test Cases

System: Facial Recognition Based Attendance Taking System				
Test Case ID: TC1.01		**Test Case Name:** Login using valid student login details		
Sub System Name: Account Management Module		**Test Priority (Low/ Medium / High):** High		
Design By: Lee Yan Jie		**Design Date:** 15th July 2022		
Executed By: Lee Yan Jie		**Execute Date:** 31st July 2022		
Description: Test the system to be able to let the students to login to their student accounts while input the valid login details.				
Pre-conditions: User has a valid student account.				
Step	**Action**	**Expected System Response**	**Pass / Fail**	**Comments**
1	Click on the student email text box provided.			
2	Enter a valid student email address. Example: leeyj-wp19@student.tarc.edu.my			
3	Click on the password text box provided.			
4	Enter a valid password. Example: LeeYanJie			
5	Click the login button.	System will verify the student login details. The user is verified and successfully logged in to their respective profile.	Pass	
Post-conditions: Student is successfully logged into the student account.				

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC1.02	**Test Case Name:** Login using valid staff login details
Sub System Name: Account Management Module	**Test Priority (Low/ Medium / High):** High
Design By: Lee Yan Jie	**Design Date:** 15th July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022

Description:

Test the system to be able to let the staffs to login to their staff accounts while input the valid login details.

Pre-conditions:

User has a valid staff account.

Step	Action	Expected System Response	Pass / Fail	Comments
1	Click on the staff email text box provided.			
2	Enter a valid staff email address. Example: staff1@staff.tarc.edu.my			
3	Click on the password text box provided.			
4	Enter a valid password. Example: 123			
5	Click the login button.	System will verify the staff login details. The user is verified and successfully logged in to their respective profile.	Pass	

Post-conditions:

Staff is successfully logged into the staff account.

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC1.03	**Test Case Name:** Login using valid student email but invalid password
Sub System Name: Account Management Module	**Test Priority (Low/ Medium / High):** High
Design By: Lee Yan Jie	**Design Date:** 15th July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022
Description: Test the system to be able to verify the invalid password and restrict the student from login to their student account even though the student email address is correct.	
Pre-conditions: User has a valid student account.	

Step	Action	Expected System Response	Pass / Fail	Comments
1	Click on the student email text box provided.			
2	Enter a valid student email address. Example: leeyj-wp19@student.tarc.edu.my			
3	Click on the password text box provided.			
4	Enter an invalid password. Example: invalid123			
5	Click the login button.	System will verify the student login details. The user is not verified and failed to login to their respective profile due to unmatched email and password.	Pass	An error message will be displayed.

Post-conditions:
Student failed to login to the student account. He or she is required to re-enter login details.

System: Facial Recognition Based Attendance Taking System				
Test Case ID: TC1.04		**Test Case Name:** Log out of current user account		
Sub System Name: Account Management Module		**Test Priority (Low/ Medium / High):** Low		
Design By: Lee Yan Jie		**Design Date:** 15th July 2022		
Executed By: Lee Yan Jie		**Execute Date:** 31st July 2022		
Description: Test the system to be able to allow user log out of their respective profile.				
Pre-conditions: User has already login into their student or staff account successfully.				
Step	**Action**	**Expected System Response**	**Pass / Fail**	**Comments**
1	Click on the "X" button at the upper right corner on the header.	Users should be redirected to the login page.	Pass	
Post-conditions: User is successfully logged out from their user account				

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC1.05	**Test Case Name:** Password recovering using valid user name and user ID to send 6-digit code to email address
Sub System Name: Account Management Module	**Test Priority (Low/ Medium / High):** Medium
Design By: Lee Yan Jie	**Design Date:** 15th July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022
Description: Test the system to be able to let the users to send email for password recovery request while input the valid user details.	
Pre-conditions: User has a valid account.	

Step	Action	Expected System Response	Pass / Fail	Comments
1	Click on the user name text box provided.			
2	Enter a valid user name. Example: Lee Yan Jie			
3	Click on the user ID text box provided.			
4	Enter a valid user ID. Example: 2005661			
5	Click on the student email text box provided.			
6	Enter a valid student email address. Example: leeyj-wp19@student.tarc.edu.my			
7	Click the “Send Digit Code to Email Address” button.	System will verify the user details. The user verified and successfully sent an email to his or her email address.	Pass	A pop-up message indicates email sent.
Post-conditions: User successfully receive the digit code from his or her email for password recovery.				

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC1.06	**Test Case Name:** Password recovering using invalid user name or invalid user ID to send 6-digit code to email address
Sub System Name: Account Management Module	**Test Priority (Low/ Medium / High):** Medium
Design By: Lee Yan Jie	**Design Date:** 15th July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022
Description: Test the system to be able to verify the invalid user name or user ID and restrict the user from sending email to assist in recovering their password even though the user email address is correct.	
Pre-conditions: User has a valid account.	

Step	Action	Expected System Response	Pass / Fail	Comments
1	Click on the user name text box provided.			
2	Enter a valid user name. Example: Lee Yan Jie			
3	Click on the user ID text box provided.			
4	Enter an invalid user ID. Example: 2005662			
5	Click on the student email text box provided.			
6	Enter a valid student email address. Example: leeyj-wp19@student.tarc.edu.my			

7	Click the "Send Digit Code to Email Address" button.	System will verify the user details. The user is not verified and failed to send email to their email address due to unmatched user name and user ID.	Pass	An error message will be displayed.

Post-conditions:

User failed to send digit code to his or her email address. He or she is required to re-enter user details.

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC1.07	**Test Case Name:** Password recovering using valid digit code received by email address
Sub System Name: Account Management Module	**Test Priority (Low/ Medium / High):** High
Design By: Lee Yan Jie	**Design Date:** 15th July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022

Description:

Test the system to be able to let the users to recover their password while input the valid digit code.

Pre-conditions:

User has a valid account, and have received the password recovery email.

Step	Action	Expected System Response	Pass / Fail	Comments
1	Click on the digit code text box provided.			
2	Enter a valid digit code. Example: 104642			
3	Click the "Confirm Reset Password" button.	System will verify the digit code. The user is verified and successfully redirected to the update password panel.	Pass	

Post-conditions:

User is redirected to the update password panel to input his or her new password.

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC1.08	**Test Case Name:** Password recovering using invalid digit code received by email address
Sub System Name: Account Management Module	**Test Priority (Low/ Medium / High):** High
Design By: Lee Yan Jie	**Design Date:** 15th July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022

Description:

Test the system to be able to verify the invalid digit code and restrict the user from recovering their password.

Pre-conditions:

User has a valid account, and have received the password recovery email.

Step	Action	Expected System Response	Pass / Fail	Comments
1	Click on the digit code text box provided.			
2	Enter an invalid digit code. Example: 104643			
3	Click the "Confirm Reset Password" button.	System will verify the digit code. The user is not verified and failed to recover their password due to unmatched digit code from the database.	Pass	An error message will be displayed.

Post-conditions:

User failed to recover his or her password due to invalid input of digit code.

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC1.09	**Test Case Name:** Password changing by inputting valid new password
Sub System Name: Account Management Module	**Test Priority (Low/ Medium / High):** Low
Design By: Lee Yan Jie	**Design Date:** 15th July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022
Description: Test the system to be able to let the user change password when new password input is valid.	
Pre-conditions: User has a valid account, and have redirected to the update password panel.	

Step	Action	Expected System Response	Pass / Fail	Comments
1	Click on the new password text box provided.			
2	Enter new password. Example: YanJie123			
3	Click on the confirm password text box provided.			
4	Re-enter password as same as the new password. Example: YanJie123			
5	Click the “Confirm Password Change” button.	System will verify the new password. The password is valid and is recovered. User is redirected automatically back to the login page.	Pass	A pop-up message indicates password is changed.

Post-conditions:
User is redirected to the login page while the new password is saved in the database.

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC1.10	**Test Case Name:** Password changing by inputting the new password as the same is the old password
Sub System Name: Account Management Module	**Test Priority (Low/ Medium / High):** Low
Design By: Lee Yan Jie	**Design Date:** 15th July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022

Description:

Test the system to be able to verify the new password as the same as the old password, and restrict the user from changing their password.

Pre-conditions:

User has a valid account, and have redirected to the update password panel.

Step	Action	Expected System Response	Pass / Fail	Comments
1	Click on the new password text box provided.			
2	Enter new password same as old password. Example: LeeYanJie			
3	Click on the confirm password text box provided.			
4	Re-enter password as same as the new password. Example: LeeYanJie			
5	Click the “Confirm Password Change” button.	System will verify the new password. The password is invalid and failed to be recovered due to being the same as the old password.	Pass	An error message will be displayed.

Post-conditions:

User will remain at the same page to input another new password or to return to login page.

5.3.2 Admin Module Test Cases

System: Facial Recognition Based Attendance Taking System				
Test Case ID: TC2.01		**Test Case Name:** Register new member with valid user details input		
Sub System Name: Admin Module		**Test Priority (Low/ Medium / High):** High		
Design By: Lee Yan Jie		**Design Date:** 17th July 2022		
Executed By: Lee Yan Jie		**Execute Date:** 31st July 2022		
Description: Test the system to be able to register new member when user input is valid.				
Pre-conditions: User has login to an admin account.				
Step	**Action**	**Expected System Response**	**Pass / Fail**	**Comments**
1	Select the user category. Example: Student			
2	Enter user information accordingly.			
3	Select user gender. Example: Click on “Female”			
4	Click the “Add Record to Database” button.	System will verify the user details. The user details are valid. New user is added in database.	Pass	A pop-up message indicates user is saved in database.
Post-conditions: The user records will have new entry as the new member is saved in the database.				

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC2.02	**Test Case Name:** Register new member with invalid user details input
Sub System Name: Admin Module	**Test Priority (Low/ Medium / High):** Medium
Design By: Lee Yan Jie	**Design Date:** 17th July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022
Description: Test the system to be able to verify the invalid contact number, and restrict user from registration of new member.	
Pre-conditions: User has login to an admin account.	

Step	Action	Expected System Response	Pass / Fail	Comments
1	Select the user category. Example: Student			
2	Enter user information accordingly.			
3	Select user gender. Example: Click on “Female”			
4	Click on the contact number text box provided.			
5	Enter an invalid contact number. Example: LeeYanJie			
6	Click the “Add Record to Database” button.	System will verify the user details. The user details are invalid and failed to be added to the database due to invalid data type input for contact number.	Fail	System did not restrict new user entry.

Post-conditions:
The user records will have new entry as the new member is saved in the database.

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC2.03	**Test Case Name:** Register new member without selecting user category
Sub System Name: Admin Module	**Test Priority (Low/ Medium / High):** Medium
Design By: Lee Yan Jie	**Design Date:** 17th July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022
Description: Test the system to be able to verify the invalid user category, and restrict user from registration of new member.	
Pre-conditions: User has login to an admin account.	

Step	Action	Expected System Response	Pass / Fail	Comments
1	Enter user information accordingly.			
2	Select user gender. Example: Click on “Female”			
3	Click the “Add Record to Database” button.	System will verify the user details. The user details are invalid and failed to be added to the database due to lack of mention of the user category.	Pass	An error message will be displayed.

Post-conditions:
Admin fails to add new member to the student records and will remain at the same page.

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC2.04	**Test Case Name:** Register new member with invalid confirm password input
Sub System Name: Admin Module	**Test Priority (Low/ Medium / High):** Medium
Design By: Lee Yan Jie	**Design Date:** 17th July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022
Description: Test the system to be able to verify the invalid user password, and restrict user from registration of new member.	
Pre-conditions: User has login to an admin account.	

Step	Action	Expected System Response	Pass / Fail	Comments
1	Select the user category. Example: Student			
2	Enter user information accordingly.			
3	Select user gender. Example: Click on “Female”			
4	Click on the password text box provided.			
5	Enter a valid password. Example: LeeYanJie			
6	Click on the confirm password text box provided.			
7	Enter another password that is different from the previous input.			

8	Click the "Add Record to Database" button.	System will verify the new password. The password is invalid and failed to be added to the database due to unmatched password with confirm password.	Pass	An error message will be displayed.

Post-conditions:

Admin fails to add new member to the student records and will remain at the same page.

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC2.05	**Test Case Name:** View user records
Sub System Name: Admin Module	**Test Priority (Low/ Medium / High):** Low
Design By: Lee Yan Jie	**Design Date:** 17th July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022

Description:

Test the system to be able to allow admin to view user records.

Pre-conditions:

User has login to an admin account.

Step	Action	Expected System Response	Pass / Fail	Comments
1	Click on the "View Students Records" button.	Admin should be redirected to the student database portal.	Pass	
2	Click on the "X" button at the upper right corner on the header.	Admin should be redirected to the admin portal.	Pass	

Post-conditions:

Admin may view student records and return to the admin portal.

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC2.06	**Test Case Name:** Update user information with valid user details input
Sub System Name: Admin Module	**Test Priority (Low/ Medium / High):** High
Design By: Lee Yan Jie	**Design Date:** 17th July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022
Description: Test the system to be able to allow admin to update user records.	
Pre-conditions: User has login to an admin account, and is viewing students' records.	

Step	Action	Expected System Response	Pass / Fail	Comments
1	Select a student to be updated. Example: Test User One	Admin should be redirected to the action available page with buttons for admin to select what changes to make to the user selected.	Pass	
2	Click on the "Update Student Info" button.	Admin should be redirected to the record update portal where student info is listed and can be edited.	Pass	
3	Enter user information accordingly.			
4	Select user gender. Example: Click on "Female"			
5	Click on the "Submit Record" button.	System will verify the user details. The user details are valid. Existing user is updated in database.	Pass	A pop-up message indicates user is updated in database.

Post-conditions:
The user records will be updated and saved in the database. The admin is redirected to the admin portal.

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC2.07	**Test Case Name:** Reverse action when updating user information
Sub System Name: Admin Module	**Test Priority (Low/ Medium / High):** Low
Design By: Lee Yan Jie	**Design Date:** 17th July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022
Description: Test the system to be able to allow admin to cancel actions and not update user records.	
Pre-conditions: User has login to an admin account, and is viewing students' records.	

Step	Action	Expected System Response	Pass / Fail	Comments
1	Select a student to be updated. Example: Test User One	Admin should be redirected to the action available page with buttons for admin to select what changes to make to the user selected.	Pass	
2	Click on the "Update Student Info" button.	Admin should be redirected to the record update portal where student info is listed and can be edited.	Pass	
3	Enter user information accordingly.			
4	Select user gender. Example: Click on "Female"			
5	Click on the "X" button at the upper right corner on the header.	Admin should be redirected to the admin portal.	Pass	

Post-conditions:
The user records are not updated and saved in the database. The admin is redirected to the admin portal.

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC2.08	**Test Case Name:** Delete user that already existed
Sub System Name: Admin Module	**Test Priority (Low/ Medium / High):** High
Design By: Lee Yan Jie	**Design Date:** 17th July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022
Description: Test the system to be able to allow admin to delete a user record.	
Pre-conditions: User has login to an admin account, and is viewing students' records.	

Step	Action	Expected System Response	Pass / Fail	Comments
1	Select a student to be updated. Example: Test User One	Admin should be redirected to the action available page with buttons for admin to select what changes to make to the user selected.	Pass	
2	Click on the "Delete Student" button.	A pop-up confirmation message should be available for user to allow delete action.	Pass	
3	Click on the "Yes" button	System will delete the user details from the database, including relevant image files	Pass	A pop-up message indicates user is deleted from the database.

Post-conditions:
The user record is deleted from the database. The admin is redirected to the admin portal.

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC2.09	**Test Case Name:** Register new member with invalid email.
Sub System Name: Admin Module	**Test Priority (Low/ Medium / High):** Medium
Design By: Lee Yan Jie	**Design Date:** 17th July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022

Description:

Test the system to be able to verify the invalid email address, and restrict user from registration of new member.

Pre-conditions:

User has login to an admin account.

Step	Action	Expected System Response	Pass / Fail	Comments
1	Select the user category. Example: Student			
2	Enter user information accordingly.			
3	Select user gender. Example: Click on “Female”			
4	Click on the email text box provided.			
5	Enter an invalid email address. Example: @hotmail.com			
8	Click the “Add Record to Database” button.	System will verify the user details. The email is invalid and student is failed to be added to the database due to invalid email address.	Fail	

Post-conditions:

The user records will have new entry as the new member is saved in the database.

5.3.3 Staff Module Test Cases

System: Facial Recognition Based Attendance Taking System				
Test Case ID: TC3.01		**Test Case Name:** View student's attendance record		
Sub System Name: Staff Module		**Test Priority (Low/ Medium / High):** Low		
Design By: Lee Yan Jie		**Design Date:** 19th July 2022		
Executed By: Lee Yan Jie		**Execute Date:** 31st July 2022		
Description: Test the system to be able to allow staff to view student's attendance records.				
Pre-conditions: User has login to a staff account.				
Step	**Action**	**Expected System Response**	**Pass / Fail**	**Comments**
1	Click on the "View Attendance Lists" button.	Staff should be redirected to the student database portal.	Pass	
2	Click on the "X" button at the upper right corner on the header.	Staff should be redirected to the staff profile.	Pass	
Post-conditions: Staff may view student's attendance records and return to the admin portal.				

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC3.02	**Test Case Name:** Refresh every student's digit code
Sub System Name: Staff Module	**Test Priority (Low/ Medium / High):** High
Design By: Lee Yan Jie	**Design Date:** 19th July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022

Description:

Test the system to be able to allow staff to refresh every student's digit code.

Pre-conditions:

User has login to a staff account, and is viewing students' attendance records.

Step	Action	Expected System Response	Pass / Fail	Comments
1	Click on the "View Attendance Lists" button.	Staff should be redirected to the student database portal.	Pass	
2	Click on the "Refresh All Student's Digit Code" button.	A pop-up confirmation message should be available for user to allow refresh digit code action.	Pass	
3	Click on the "Yes" button	The student digit codes should all be refreshed.	Pass	A pop-up message indicates the digit codes are refreshed in database.

Post-conditions:

The record is refreshed, all student's digit code has changed. The staff is redirected to the staff profile.

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC3.03	**Test Case Name:** Refresh every student's attendance status
Sub System Name: Staff Module	**Test Priority (Low/ Medium / High):** High
Design By: Lee Yan Jie	**Design Date:** 19th July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022
Description: Test the system to be able to allow staff to refresh every student's attendance status.	
Pre-conditions: User has login to a staff account, and is viewing students' attendance records.	

Step	Action	Expected System Response	Pass / Fail	Comments
1	Click on the "View Attendance Lists" button.	Staff should be redirected to the student database portal.	Pass	
2	Click on the "Mark All Student's Attendance" button.	A pop-up confirmation message should be available for user to allow change of attendance status action.	Pass	
3	Click on the "Yes" button	The student digit codes should all be refreshed.	Pass	A pop-up message indicates the attendance status are refreshed as present in database.

Post-conditions:
The record is refreshed, all student's attendance status has changed to present. The staff is redirected to the staff profile.

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC3.04	**Test Case Name:** Reverse action when refreshing student's attendance records
Sub System Name: Staff Module	**Test Priority (Low/ Medium / High):** Medium
Design By: Lee Yan Jie	**Design Date:** 19th July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022

Description:

Test the system to be able to allow admin to cancel actions and not update students' attendance records.

Pre-conditions:

User has login to a staff account, and is viewing students' attendance records.

Step	Action	Expected System Response	Pass / Fail	Comments
1	Click on the "View Attendance Lists" button.	Staff should be redirected to the student database portal.	Pass	
2	Click on the "Mark All Student's Attendance" button.	A pop-up confirmation message should be available for user to allow change of attendance status action.	Pass	
3	Click on the "Cancel" button	The student digit codes should remain the same.	Pass	

Post-conditions:

The attendance status remains the same. The staff is redirected to the staff profile.

System: Facial Recognition Based Attendance Taking System				
Test Case ID: TC3.05		**Test Case Name:** Refresh the digit code of a student		
Sub System Name: Staff Module		**Test Priority (Low/ Medium / High):** High		
Design By: Lee Yan Jie		**Design Date:** 19th July 2022		
Executed By: Lee Yan Jie		**Execute Date:** 31st July 2022		
Description: Test the system to be able to allow staff to refresh a student's digit code.				
Pre-conditions: User has login to a staff account, and is viewing students' attendance records.				
Step	**Action**	**Expected System Response**	**Pass / Fail**	**Comments**
1	Select a student to be updated. Example: Test User One	Staff should be redirected to the action available page with buttons for staff to select what changes to make to the user selected.	Pass	
2	Click on the "Update Digit Code" button.	The digit code of the student is refreshed.	Pass	A pop-up message indicates the digit code is refreshed in database.
Post-conditions: The student's digit code has changed, other students are not affected. The staff is redirected to the staff profile.				

System: Facial Recognition Based Attendance Taking System				
Test Case ID: TC3.06		**Test Case Name:** Refresh the attendance status of a student		
Sub System Name: Staff Module		**Test Priority (Low/ Medium / High):** High		
Design By: Lee Yan Jie		**Design Date:** 19th July 2022		
Executed By: Lee Yan Jie		**Execute Date:** 31st July 2022		
Description: Test the system to be able to allow staff to refresh a student's attendance status.				
Pre-conditions: User has login to a staff account, and is viewing students' attendance records.				
Step	**Action**	**Expected System Response**	**Pass / Fail**	**Comments**
1	Select a student to be updated. Example: Test User One	Staff should be redirected to the action available page with buttons for staff to select what changes to make to the user selected.	Pass	
2	Click on the "Refresh Attendance" button.	A pop-up confirmation message should be available for user to allow change of attendance status action.	Pass	
3	Click on the "Yes" button	The attendance of the student is refreshed.	Pass	A pop-up message indicates the attendance status is refreshed in database.
Post-conditions: The student's attendance has changed, other students are not affected. The staff is redirected to the staff profile.				

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC3.07	**Test Case Name:** Reverse action when updating a student's attendance records
Sub System Name: Staff Module	**Test Priority (Low/ Medium / High):** Medium
Design By: Lee Yan Jie	**Design Date:** 19th July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022
Description: Test the system to be able to allow admin to cancel actions and not update students' attendance records.	
Pre-conditions: User has login to a staff account, and is viewing students' attendance records.	

Step	Action	Expected System Response	Pass / Fail	Comments
1	Select a student to be updated. Example: Test User One	Staff should be redirected to the action available page with buttons for staff to select what changes to make to the user selected.	Pass	
2	Click on the "Refresh Attendance" button.	A pop-up confirmation message should be available for user to allow change of attendance status action.	Pass	
3	Click on the "No" button	The attendance of the student is kept the same.	Pass	A pop-up message shows the attendance status for the student which is unchanged.

Post-conditions:
The attendance status of the student remains the same. The staff is redirected to the staff profile.

5.3.4 Attendance Taking Module Test Cases

System: Facial Recognition Based Attendance Taking System				
Test Case ID: TC4.01		**Test Case Name:** Verify student identity for facial recognition with valid student details		
Sub System Name: Attendance Taking Module		**Test Priority (Low/ Medium / High):** High		
Design By: Lee Yan Jie		**Design Date:** 21st July 2022		
Executed By: Lee Yan Jie		**Execute Date:** 31st July 2022		
Description: Test the system to be able to let the students to take attendance while input the valid student details to verify student identity.				
Pre-conditions: User has a valid student account.				
Step	**Action**	**Expected System Response**	**Pass / Fail**	**Comments**
1	Click on the student name text box provided.			
2	Enter a valid student name. Example: Lee Yan Jie			
3	Click on the student ID text box provided.			
4	Enter a valid student ID. Example: 2005661			
5	Click on the attendance code text box provided.			
6	Enter a valid attendance code accordingly. Example: 748236			

7	Click the "Scan for Attendance" button.	System will verify the student details. The user identity is verified and successfully allow access for attendance taking.	Pass	A pop-up message indicates student is verified.

Post-conditions:

Student may proceed for attendance taking.

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC4.02	**Test Case Name:** Verify student identity for facial recognition with invalid student details
Sub System Name: Attendance Taking Module	**Test Priority (Low/ Medium / High):** High
Design By: Lee Yan Jie	**Design Date:** 21st July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022

Description:

Test the system to be able to let the students to take attendance while input the invalid student details to verify student identity.

Pre-conditions:

User has a valid student account.

Step	Action	Expected System Response	Pass / Fail	Comments
1	Click on the student name text box provided.			
2	Enter a valid student name. Example: Lee Yan Jie			
3	Click on the student ID text box provided.			
4	Enter a valid student ID. Example: 2005661			

5	Click on the attendance code text box provided.			
6	Enter an invalid attendance code different from what user needs. Example: 888888			
7	Click the “Scan for Attendance” button.	System will verify the student details. The user identity is not verified and successfully allow access for attendance taking.	Pass	An error message indicates student is not verified.
Post-conditions: Student is not allowed to proceed for attendance taking. Student remains at the verifying identity page.				

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC4.03	**Test Case Name:** Take attendance with valid student face
Sub System Name: Attendance Taking Module	**Test Priority (Low/ Medium / High):** High
Design By: Lee Yan Jie	**Design Date:** 21st July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022
Description: Test the system to be able to let the students to take attendance while using the face of the student that is correct and matches the identity of student verified.	
Pre-conditions: User has a valid student account, and has verified his or her identity.	

Step	Action	Expected System Response	Pass / Fail	Comments
1	Enter each textbox accordingly with valid student details. Example: Lee Yan Jie 2005661 748236			
2	Click the “Scan for Attendance” button.	System will verify the student details. The user identity is verified and successfully allow access for attendance taking.	Pass	A pop-up message indicates student is verified.
3	Look at the camera with frontal face and smile.	System will recognize the student and mark his or her attendance.	Pass	A pop-up message indicates student attendance is taken.

Post-conditions:
Student attendance is changed from absent to present. Student will be redirected to the verifying identity page.

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC4.04	**Test Case Name:** Take attendance with invalid student face.
Sub System Name: Attendance Taking Module	**Test Priority (Low/ Medium / High):** High
Design By: Lee Yan Jie	**Design Date:** 21st July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022

Description:

Test the system to restrict students from taking attendance while using the face of the student that is incorrect and does not match the identity of student verified.

Pre-conditions:

User has a valid student account, and has verified his or her identity.

Step	Action	Expected System Response	Pass / Fail	Comments
1	Enter each textbox accordingly with the student details different from the user who will perform the face recognition. Example: Lee Yan Jie 2005661 748236			The user who will scan their face later is named Lee Ying Shan, which is a different student from Lee Yan Jie's faceprints.
2	Click the "Scan for Attendance" button.	System will verify the student details. The user identity is verified and successfully allow access for attendance taking.	Pass	A pop-up message indicates student is verified.
3	Look at the camera with frontal face and smile.	System will not recognize the student, and after 15 seconds the system will prompt message indicating failure to take attendance.	Pass	A pop-up message indicates student attendance is not taken.

Post-conditions:

Student attendance remain unchanged. Student will be redirected to the verifying identity page.

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC4.05	**Test Case Name:** Repeat taking attendance for students
Sub System Name: Attendance Taking Module	**Test Priority (Low/ Medium / High):** High
Design By: Lee Yan Jie	**Design Date:** 21st July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022
Description: Test the system to restrict students from taking attendance when the student has already taken his or her attendance before.	
Pre-conditions: User has a valid student account, and has verified his or her identity.	

Step	Action	Expected System Response	Pass / Fail	Comments
1	Enter each textbox accordingly with valid student details. Example: Lee Yan Jie 2005661 748236			
2	Click the "Scan for Attendance" button.	System will verify the student details. The user identity is verified and successfully allow access for attendance taking.	Pass	A pop-up message indicates student is verified.
3	Look at the camera with frontal face and smile.	System will recognize the student and realize that his or her attendance is already present	Pass	An error message informs student that he or she has already taken attendance.

Post-conditions:
Student attendance remain unchanged. Student will be redirected to the verifying identity page.

System: Facial Recognition Based Attendance Taking System				
Test Case ID: TC4.06		**Test Case Name:** Perform Train Image Action		
Sub System Name: Attendance Taking Module		**Test Priority (Low/ Medium / High):** High		
Design By: Lee Yan Jie		**Design Date:** 21st July 2022		
Executed By: Lee Yan Jie		**Execute Date:** 31st July 2022		
Description: Test the system to allow student to take training image for machine learning for 300 times.				
Pre-conditions: User has a valid student account, and has login his or her student account				
Step	**Action**	**Expected System Response**	**Pass / Fail**	**Comments**
1	Click the "Train Image" button.	System will open the camera and take screenshots of the user facial image when captured for 300 times.	Pass	A pop-up message indicates student faceprints is stored.
Post-conditions: The training image is successfully stored in the database.				

System: Facial Recognition Based Attendance Taking System				
Test Case ID: TC4.07		**Test Case Name:** Perform Train Image Action over system limits		
Sub System Name: Attendance Taking Module		**Test Priority (Low/ Medium / High):** High		
Design By: Lee Yan Jie		**Design Date:** 21st July 2022		
Executed By: Lee Yan Jie		**Execute Date:** 31st July 2022		
Description: Test the system to allow student to take training image for machine learning for 3000 times.				
Pre-conditions: User has a valid student account, and has login his or her student account				
Step	**Action**	**Expected System Response**	**Pass / Fail**	**Comments**
1	Click the "Train Image" button.	System will open the camera and take screenshots of the user facial image when captured for 3000 times.	Fail	
Post-conditions: The training image is not stored in the database. The system is not responding and forced to terminate the program.				

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC4.08	**Test Case Name:** Take attendance with valid student face with different appearance
Sub System Name: Attendance Taking Module	**Test Priority (Low/ Medium / High):** Medium
Design By: Lee Yan Jie	**Design Date:** 21st July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022

Description:

Test the system to be able to let the students to take attendance while using the face of the student that is correct and matches the identity of student verified but with different hairstyle, wearing make-up and spectacles.

Pre-conditions:

User has a valid student account, and has verified his or her identity.

Step	Action	Expected System Response	Pass / Fail	Comments
1	Enter each textbox accordingly with valid student details. Example: Lee Yan Jie 2005661 748236			
2	Click the "Scan for Attendance" button.	System will verify the student details. The user identity is verified and successfully allow access for attendance taking.	Pass	A pop-up message indicates student is verified.
3	Look at the camera with frontal face and smile.	System will recognize the student and mark his or her attendance.	Pass	A pop-up message indicates student attendance is taken.

Post-conditions:

Student attendance is changed from absent to present. Student will be redirected to the verifying identity page.

System: Facial Recognition Based Attendance Taking System	
Test Case ID: TC4.09	**Test Case Name:** Take attendance with valid student face with poor lighting condition
Sub System Name: Attendance Taking Module	**Test Priority (Low/ Medium / High):** Medium
Design By: Lee Yan Jie	**Design Date:** 21st July 2022
Executed By: Lee Yan Jie	**Execute Date:** 31st July 2022

Description:

Test the system to be able to let the students to take attendance while using the face of the student that is correct and matches the identity of student verified but under poor lighting condition where the light source is at the back of the student.

Pre-conditions:

User has a valid student account, and has verified his or her identity.

Step	Action	Expected System Response	Pass / Fail	Comments
1	Enter each textbox accordingly with valid student details. Example: Lee Yan Jie 2005661 748236			
2	Click the "Scan for Attendance" button.	System will verify the student details. The user identity is verified and successfully allow access for attendance taking.	Pass	A pop-up message indicates student is verified.
3	Look at the camera with frontal face and smile.	System will recognize the student and mark his or her attendance.	Fail	

Post-conditions:

Student attendance remain unchanged. Student will be redirected to the verifying identity page.

Chapter 6

Discussions and Conclusion

6 Discussions and Conclusion

6.1 Summary

In conclusion, the Facial Recognition based Attendance Taking System is a feasible project that can be achieved in the future by implementing this method of marking student's attendance through identifying student's unique faceprints. However, this method could be hard to implement and thus in the end depends on the school's management decision making on whether or not student's attendance is important to this extend. Throughout this project, I have encountered uncountable problems and seek many helps from my family, friends as well as the supervisor herself, to gather their valuable opinion when developing this Attendance Taking System. In most cases, when my program runs into error or when the output differs from my expectation, I was able to solve with the help of anonymous users from the internet.

The successful of developing this Facial Recognition based Attendance Taking System is due to the user-friendliness of the developing tools and easy to learn methodologies that I have make good use of during the development phase for this project. For example, Visual Studio Code are the most important tool as it is my main development platform. Through Visual Studio Code I was able to easily implement Python libraries and to connect with SQLite 3 Database without running into system error. Other than that, the methodologies that I have used, Haar Cascade Classifier as well as LBPH are helpful in terms of recognizing the human faces. Not to mention that, there are few websites that were helpful for online researches for the relevant topic, such as the TARUC Library Repository, Stack Overflow, GitHub, and so much more.

The Facial Recognition based Attendance Taking System applies the software process model of prototyping. The system is developed according to a well-defined life cycle along with deadlines to follow with in order to ensure that the project can be kept on track and measured easily in terms of performance. At first during literature review, the theory of facial recognition is studied, understood, and the reason for changing with the attendance taking methodologies are explained in details. This process is crucial in defining the backbone of the prototype project. For example, knowing the strength and weakness of each machine learning algorithms helps in making decision which methods is most suitable to be implemented for TARUC attendance taking system.

Not to mention that, after investigation of the topic, the next step of discussing the design of the attendance taking system have enhance the understanding of the project's overall scope as well as the activity flow. In order word, the diagrams that were prepared for the prototype acted as a guideline before actual development to ensure the process will proceed smoothly with lesser possibility of error and mistakes. For example, during the design stage, the modules' functional logic, databases' information, user interface wireframe, hardware and software requirements, as well as the overall system architecture can be described in details and determined in advance.

Moving on to the coding and implementation stage where the actual coding is generated based on the design specifications as mentioned earlier. The Attendance Taking System is built entirely phase by phase, slowly by achieving every single milestone set at the beginning of the project. Although the project is difficult due to lack of manpower, but through dividing each task separately into manageable sections, the process has become more structured and easier to monitor the progress. Other than that, the guidance and advices by my supervisor from time to time has ease the development process. The most time-consuming step would be developing the facial recognition part for attendance taking, which is no doubt the core module for this prototype project. Before moving on to the next phase, the complete developed system is tested continuously and improved until the prototype satisfies the user requirements. At this step, the system is put into a suitable testing environment, where black box testing is performed on checking the system functionalities as well as its quality attributes such as performance, reliability, recoverability, and etc. Any defects or system flaws found in this phase will be jot down and fixed if possible. Some problems that were beyond the developer's capability have been left for future enhancements. The goal is to produce a Attendance Taking System that was bug-free, stable, and fulfill user requirements at the same time.

6.2 Achievements

The achievements of the Facial Recognition based Attendance Taking System is to be able to satisfy the objectives as declared at the beginning of this project. All the functionalities of this prototype project that was mentioned in the earlier chapters of this report has been completed as it was able to be developed and delivered successfully as expected. Not only that, more functionalities were further added in to the system. However, sad to say there are certain limitations encountered with the prototype and could not be avoided not solved within the time constraint. Therefore, it would be best that in the upcoming future, one day the limitations can be overcome or solved, as this would greatly enhance the system's usability and efficiency to be more widely implemented for the higher educational institutions.

To be more concise, the following shows the objectives of the Facial Recognition based Attendance Taking System that are achieved throughout the project:

1. **To identify challenges that faced in facial recognition.**

   Before the development of the system, deep investigation has been carried out to understand the background of facial recognition, which includes the challenges faced and the reason for why Malaysia is not implementing widely this new technology. This is because of the technological challenges such as human aging, different facial expressions, facial advances through surgeries, as well as pose variations makes it difficult for the system to recognize a person accurately, thus having low reliability and hard to be implemented to identify a person in real life application. Other than that, is the social challenges such as data privacy concerns, low reliability and lack of trust, racial bias issues, as well as lack of laws and regulations. All these will become the problem to be solved before the Facial Recognition based Attendance Taking System can be actually developed and implemented to the society.

2. **To analyze advantage and contribution in software industry.**

   Every cloud has a silver lining, which fairly describes how Facial Recognition contributes in improving mankind's living standards. The most significant example of this is where Facial Recognition is used in account management that allows users to easily unlock their phone or to login their account. This highly improves the efficiency and security of the account management. Other than that, software such as Facebook,

Google Photo, as well as iPhone's gallery uses photo tagging features that apply the knowledge of Facial Recognition to sort the images and identify individuals. This enhances the user friendliness as well as expanding functionality to create more memories. However, this feature has later been removed from Facebook to eliminate growing societal concerns. Face Recognition has also benefited the healthcare industry with the new software developed, Face2Gene, that assists the medical experts in finding genetic disorders, and to track dysmorphic features. Lastly, Facial Recognition plays an important role in bringing entertainment in order to slowly gain user's trust and acceptance towards this new technology. One of the examples is Face DNA Test which can validate the relationship between family members just by scanning their faceprints. Knowing that the Facial Recognition brings contributions to the society can boost our confidence towards this technology, and give hope in expecting it to be widely used in the future.

3. **To analyze potential algorithms for facial recognition.**

The system developed has also achieved the objective of analyzing the algorithms and methodology that produced faceprints for the past century. For example, Haar Cascade Classifier, Principal Component Analysis, RGB Filter are algorithms used for face detection. Other than that, Eigenfaces, Discrete Cosine Transform, as well as Laplacian of Gaussian are methodologies that performs feature extractions to store either matrix, complicated numbers or any sorts of faceprints information into the database. Lastly, for facial recognition where the system find matching between a person and the faceprint bank includes Support Vector Machine, Local Binary Patterns and Three-Dimensional Recognition Technologies. To enhance the facial recognition process, there are methods to train the database in the first place, which involves machine deep learning, such as Convolutional Neural Network and Feedforward Neural Network, which are both great breakthroughs of Artificial Neural Networks and AI development.

4. **To develop a face recognition prototype to identify a person based on facial features**

As mentioned earlier, a face recognition prototype that fulfills the user requirements, core functionalities have been developed and is able to successfully identify at least 80% of the test subjects face based on the faceprints stored in the database. The quality of each image has also been improved, as if the face images inside the training set is very blur, then the accuracy of the face recognition for this kind of system will be very

low as well. This prototype is mainly developed using a laptop. The reason behind this is due to the need of running and training the deep learning faceprints dataset will require hardware with high memory storage and processor.

5. **To validate the proposed face recognition prototype in terms of accuracy and performance.**

   The quality attributes that are valued include Performance, Reliability as well as Security. The performance can be shown by how fast and efficiently the system fulfills tasks such as to recognize a student and take his or her attendance. For this case, the average time taken for the system to recognize a student is at 6 seconds, where the fastest is within a second. Reliability on the other hand is ensuring that the system responds all the time and gives accurate results. Most of the student face are recognizable, but there are also some case where false positive or false negative occurs. Overall, the system is considered to be accurate with the results achieved. Lastly, regarding the security part, is where the admin takes responsibility for keeping the data of the students and staff safe.

Other than the objectives that were achieved, I am grateful that I was able to make good use of my ability, skills, knowledge, experiences that were gained from previous courses I have taken before to apply them in order to develop this Facial Recognition based Attendance Taking System. To me, this is the greatest achievement ever, since all the information I learnt has been applied all together in producing such successful project of a prototype system that combines innovative ideas with high quality. Because of the understanding with Software Engineering, the documentation is also completed precisely, with detailed explanation and suitable diagrams accompanied so that it can be well used to clarify the project for future readers to avoid confusion.

6.3 Contributions

The main contribution of this project is to improve the society's understanding regarding about the topic of facial recognition, and at the same time enhance their acceptance towards this new technology. This is because people neglect using facial recognition due to the challenges and bottleneck with the current technology. However, with more and more people aware of this technology advancement, the possibility of implementing facial recognition could be highly improved. Therefore, the goal of this project is to ensure that the readers can get all the necessary information about facial recognition, and one of the potential applications of this technology, which is in the attendance taking system. In the future, when there are students who are interested in this topic, could maybe get ideas or inspirations from this research-based project, and develop more useful application for the society.

Other than that, the contribution of this project is to ease the attendance taking process by providing alternative solutions such as using facial recognition to identify the student. The advantage is that this way the attendance accuracy can be improved as faking attendance will no longer be an issue to solve with. This provides the staff and school management team more control and trust towards the attendance system applied to students. Not to mention that, with such strict attendance taking system, student will be forced to attend class, which might potentially improve their academic results if they pay attention to class. At the very end, by applying facial recognition technology to the attendance taking system will definitely improve a school's reputation and image.

The significance of this project is that the Facial Recognition based Attendance Taking System is proposed and developed for the academic institutions such as Tunku Abdul Rahman University College (TARUC). This system is developed to bring convenience and benefit the TARUC staff and students by introducing new methods of taking students attendance. From the student's perspective, students are more regulated by the system, thus becoming more discipline and more motivated to attend class. Other than that, student will no longer be burdened by other classmates who would ask help for faking their attendance, which means this system can unintentionally reduce student's social problem. From the staff's perspective, the attendance taking system helps monitoring students attendance so they manual monitoring could be reduced, lecturers are also given more convenient way for marking student's attendance with short keys rather than repeating the process over again for every single student.

6.4 Limitations and Future Improvements

Although the Facial Recognition based Attendance Taking System as been developed, where most of its functionalities have been completed as a prototype in general. It is undeniable that there were certain limitations that makes the prototype imperfect. The limitations and future improvements have been listed as the following:

1. **Devices Incompatibility**

   There are many functions unable to carry out as well as poor user interface design due to using laptop to develop this prototype instead of using mobile application. The solution for this limitation is by performing software reengineering in the future using the rework strategy to change the system in terms of abstraction, alteration and refinement. Firstly, by extracting the information from the code of the existing system such as the functionalities and the design of the system, future developers can create an abstract model about the system that has a higher level of abstraction which is easier to understand. The user interface for the attendance taking module is also redesigned to make it more functional and convenient to use. This way, future developers can rework a new application based on the current prototype.

2. **Distributed System and Parallel Computing**

   The facial recognition requires training the faceprints with deep machine learning for the computer to be able to identify user accurately. From the project, as shown in figure 6.1, it takes more than 7 minutes to train 5000 images as data set. This reduces the efficiency of the Facial Recognition based Attendance Taking System. The solution to this is by implementing the software on cloud, to reduce the burden of the computer's processor and storage. Through parallel computing, such as OpenMP or Cuda, the time taken to train the database can be shorten to milliseconds at most. As a result, the performance of the system will be more satisfying, and more user is able to participate using this system in the future.

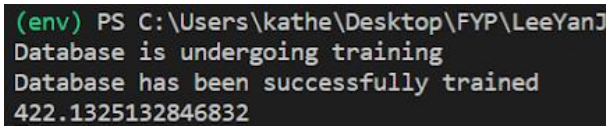


Figure 6.1: Time taken to train faceprints database

3. Lack of functionalities

Since the Facial Recognition based Attendance System is only a prototype, the features provided are considered too simple and lack of variety to be develop as a new application. For example, the system only focuses on the attendance taking part, and ignored the part for the attendance report, where the staff can view the attendance for one particular students throughout his or her study period. Other than that, the system only works for one class, which is not practical in real life situation. The solution is to integrate the prototype by combining with the current existing TARC App that provides many other functionalities, such as attendance report, manual attendance feature, class timetable, exam results and etc. The main goal of this prototype was to enhance from the current app at the first place, thus it makes sense to apply facial recognition in the TARC App which is feasible in the future.

6.5 Issues and Solutions

At first, the issue that I encountered is during literature review, where I am out of idea what to research on and how to plan out this project. Meanwhile, my previous supervisor was uncontactable and thus I seek help from other lecturers who are professional with the Artificial Intelligence field. Through several consultation, the lecturers have given some ideas and guidelines with the topic, as well as shown me some journal and report that might be useful in enhancing my understanding with the topic.

Moreover, a small issue that I faced was to gathered at least 20 test subjects who are willing to assist in developing this project by sharing their faceprints which could interfere with their privacy concerns. This is because many people resist to have their facial images stored on other people's computer and finds it uncomfortable. Not only that, to fulfill the experiment, the images of a person are around 300 pieces, at three different time period, as well as three different environments with different lighting condition. These criteria are hard to achieve as it would take a lot of time to make an appointment to meet 20 students in person to gather their image as training data. The solution is to ask help from my family and friends who are closed to me and willing to support me and this project at their very best.

Other than that, during the development phase, the accuracy of the facial recognition was not up to standard, which the worst case is when it could not even recognize my own face. This problem has been difficult to solve, as several attempts of modifying the codes does not seem to improve the system performance. Through system preview with my supervisor, Ms. Mazlinda has suggested me to improve the quality and quantity of my training images. Not only that, I have eventually figured out the best way to control the confidence rate of the system to a produce a satisfying result.

Besides, another issue I have faced when developing the prototype is regarding the database. As shown in figure 6.2, an error message prompting the database is locked would always easily trigger from time to time which is hard to debug the reason why since sometimes the same procedure with not prompt this problem. Through googling websites, I realized this is a common issue that many developers face. The reason behind this issue is because normally, the error occurs when two users try to run transactions on the same tables and change the content. SQLite engine finds it abnormal and locks the database. Therefore, the user cannot run more

transactions. In my case is the staff or student is accessing the database while the admin is accessing at the same time. The solution is to use the backup copy of the same database or to ensure only one user access the database at a time.

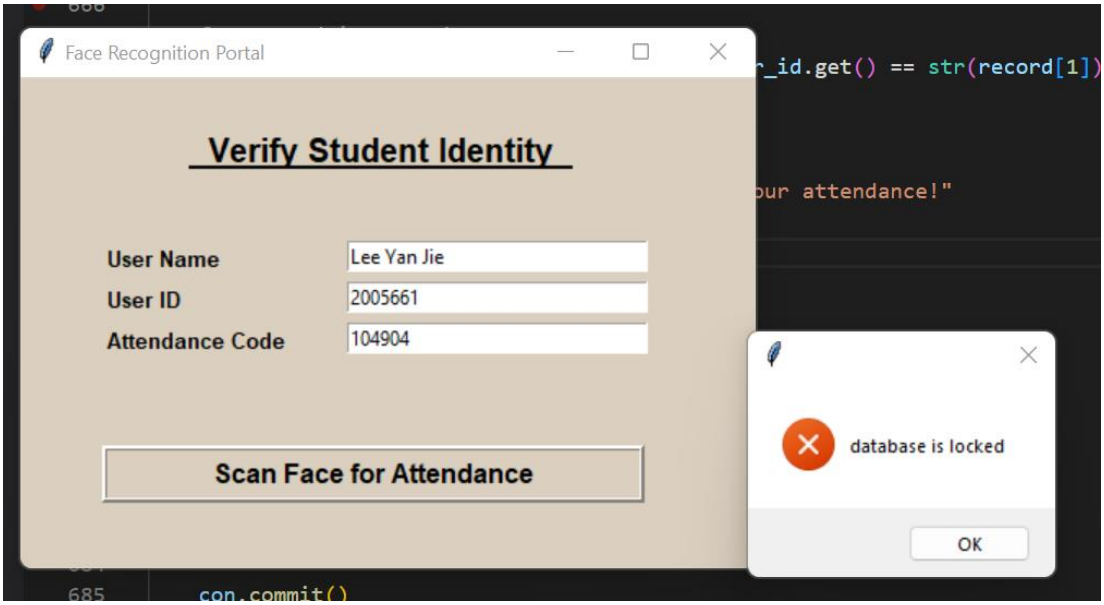


Figure 6.2: Database issue encountered during development stage

Lastly, the issue that I encountered with this project is the time constraint to develop the prototype. The system uses new technology and with only one person, it is hard to catch up the progress. It is a big challenge for me to ensure the project is delivered on time, and fulfill every user requirement before the deadline given. The solution is to plan my time carefully for everyday through daily planner and setting weekly target on what tasks to be completed. Fortunately, in the end the system is successfully developed on time with complete functionalities.

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