Chapter I

Background

1.1 Introduction

Recently, IoT (Internet of Things) technology has received great attention as one of the key issues for future technology. This IoT technology is expected to provide more convenient living environments to people in the near future. IoT technology is generally related with human behaviors as a commend input from various information that can be utilized to control the devices such as human face detection and human gestures. IoT technology has been also applied for the energy saving to efficiently control the limited natural resources. This information can be a key element to design and implement the smart home.

Many countries are gradually adopting smart home security control system [1] [2]. The most important part of any home security system is accurately identifying visitor who enter and leave through the door [3] [4]. An entrance guard can be managed using passwords, RFID sensors, finger prints and face recognition methods [5]. Face recognition is probably the most natural way to perform biometric authentication between human beings. Additionally, it is the second most popular biometric trait, after fingerprints [6-8].

Faces have long been a source of interest to scientists in a wide range of disciplines. In recent years, this breadth of interests, approaches and expertise has led directly to rapid advances in our understanding of many different aspects of how we perceive and process faces [9]. Face recognition is a form of computer vision that uses the face to identify or to authenticate a person. An important difference with other biometric solutions is that faces can be captured from some distance away using surveillance cameras. Therefore, face recognition can be applied without the subject knowing that he is being observed.

We have kept all the point in mind and made our system. The system is an IoT based automated Visitor Monitoring system using GSM technology provide mainly a smart phone application that stores information about visitors. This system can be applied at home, office or anywhere.

1.2 Problem statement

This paper deals with design and development of a real time human face detection system using Viola-Jones algorithm and face recognition system using FLD (Fisher's Linear Discriminant) for visitor monitoring at smart home environment. This system can simply recognize the incomer who enters or leaves whether he/she is family member or not. When a family member or an outsider arrives, the GSM modem which is attached to the system will automatically send the intruders identity (else identified as outsider) through SMS to the owner. The camera which is pre-setup at the entrance of home to capture the photograph of the incomer and the system compares the same with the database of photos of the authorized family members to check whether it is the image of the family members or not. The owner of the system (our system suggest as a parent) can get all the message in an android application where the application would be previously installed to the parent's android based smartphone. The app dynamically updates messages for the visitors where the messages carry the identity of the invader (whether he/she is familiar or not with the stored database of photos of family members, if not then it'll message as the identification of an outsider arrival).

1.3 Motivation

While convenience and comfort are the most commonly touted benefits when it comes to the smart home, it turns out the biggest reason consumers adopt the technology is something much more basic: the safety of loved ones. This and other findings were the result of a new study of nearly 1,300 consumers conducted in March 2016 by August Home and Xfinity Home to better understand perceptions of smart home and home security technology in the era of the connected home. When asked why they would consider adopting smart home technology, 63% of consumers said keeping their family safe is their top motivation [10].

The motivation for developing automated visitor monitoring systems comes from many reasons, but most prominent are convenience, security. It's a smart home system. Smart Home systems are one of the newer areas of research that have not been fully integrated into our society. However, with a sophisticated enough system, home security becomes a powerful tool that gives piece of mind and power to the user. Security systems are also a large deterrent for crime. The mere

presence of a camera will put doubt in any criminal's mind about committing a crime. There are already many security systems on the market available and in use today, however integrating the security system into the smart home gives the user a one stop access to everything in their home. If the smart home system integrates the smart phone into the system, then this means that the user will always know the status of the security of their home.

1.4 Objectives

Our objectives are:

i. Recognizing visitor using face recognition approach to provide information to home owner instantly about who are coming and leaving home and also when.

ii. Ensuring the safety of family members.

iii. Eliminating physical interference at the entrance of home.

1.5 Organization of the Thesis

This thesis has been organized to six chapters. Each chapters gives the concept regarding the current study.

Chapter I (*Background*): This chapter contains the introductory concept with preliminary definition of our system. It also includes short description of existing approaches and the objectives of this thesis.

Chapter II (*Literature Survey*): This chapter presents brief discussions with background information of our system, proper definition of required terms, algorithm, approaches, hardware according to our system.

Chapter III (*Existing Systems and Problems*): This chapter describes existing systems elaborately with their limitations. Also it contains the problems of the existing system.

Chapter IV (*Methodology*): In this chapter we briefly discuss about the basic concepts of our technique. Here the framework of the algorithm along with the parameters used is demonstrated.

Chapter V (*Experimental Results and Analysis*): This chapter demonstrates the experimental results of our system.

Chapter VI (*Conclusion and Future Plan*): In this chapter we conclude our research along with some future research direction.

Chapter II

Literature Survey

2.1 Introduction

In this chapter, a detailed theoretical background is presented on IoT and automated visitor monitoring system in smart home environment using GSM technology. On the other hand, a gentle overview on face detection, recognition approach, advantages of these approaches for monitoring a human and required hardware and software is ascertained.

2.2 IoT

The IoT refers to the connection of devices (other than typical fare such as computers and smartphones) to the Internet. Cars, kitchen appliances, and even heart monitors can all be connected through the IoT. And as the Internet of Things grows in the next few years, more devices will join that list. Principally IoT is a network of internet-connected objects able to collect and exchange data using embedded sensors [11]. Some examples of IoT may be considered such as: CHECK ON THE BODY- Aimed at helping to prevent SIDS, the Mimo monitor is a new kind of infant monitor that provides parents with real-time information about their baby's breathing, skin temperature, body position, and activity level on their smartphones, STOP DRIVING IN CIRCLES- With the use of installed sensors, mobile apps, and real-time web applications like those provided in Streetline's ParkSight service, cities can optimize revenue, parking space availability and enable citizens to reduce their environmental impact by helping them quickly find an open spot for their cars. Fig 2.1 describes HEAT YOUR HOME EFFECIENTLY- Smart

Figure 2.1: Example of IoT- HEAT YOUR HOME EFFECIENTLY [12]

thermostats like the Nest use sensors, real-time weather forecasts, and the actual activity in your home during the day to reduce your monthly energy usage by up to 30%, keeping you more comfortable, and offering to save you money on your utility bills etc. [12]. The challenge of deriving insights from the Internet of Things (IoT) has been recognized as one of the most exciting and key opportunities for both academia and industry [13].

2.3 Automated System

Automated systems eliminate the need for human interference in order to complete a task. Several industries use automated systems to increase production and reduce costs. A common example is an ATM, which can process banking transactions without a teller that shows in fig 2.2. Automated systems have been incorporated into production lines and machines for years. The main purpose of an automated system is to help speed up a process. Tasks that are time-consuming or inconvenient are often incorporated into systems. Systems have key components that allow them to function properly including a control system, a way to interpret and distribute data and a human interface. Programmable logic allows the system to process data and control it. In the computer industry, there are many tasks that do not require constant human attention. Software can be used to complete a number of different tasks and automatically post the results. Bots can be programmed to click objects on the screen, send messages at preset times or interact on social networks using artificial intelligence [14].

Figure 2.2: Example of Automated System- ATM [14]

2.4 Smart Home Environment

In today's era of 21st century the world witnessing a tangential shift in technology and innovation in a short span of time. Various innovations in the area of computing, processing and analytics are happening today. However, today the buzzword "Smart homes and IoT" is most popular among

the companies, universities, research scholars and so on. With the advent of emerging technologies and innovations like big data analytics, booming telecom sector, increasing broadband connectivity and improved processing capability of various devices and sensors, the idea of having a smart home which was looking impossible till the very recent time now seems to be feasible and possible. Smart homes today are derived from amalgamation of Internet of Everything. The way majority of our gadgets are networked together gives us a consistent control over all sub-parts of our home and the sky is the limit from there. Mobiles have changed the way we consider collaborating with the innovation in our homes and it's made a longing zest for constant association and control that was once inconceivable. Innovative thoughts are applied to every aspect revolving around a smart home to evolve it further. From point product providing single service to multi proposition systems and data driven services smart home industry has evolved to provide comfort, energy and money saving, security and luxury to users. Thus innovation, technology and customer expectation can be said as the drivers of home automation system. Today the concept of smart home has taken a leap ahead from merely being a concept to a solution which is practically implemented [15]. Universally, Smart home environments are the integration of technology and services through home networking for automating, improving, security, safety, communication, comfort and energy saving. A smart home based on WSN is using solid deployment of sensors to provide insinuate and precise monitoring [16]. Fig 2.3 shows an example of Smart Home that contains heating (such as smart thermostats), ventilation, air conditioning (HVAC), and security, as well as home appliances such as washer/dryers, ovens or refrigerators/freezers that use Wi-Fi for remote monitoring.

Figure 2.3: Example of Smart Home Environment

2.5 Face Detection

Face detection is a critical step to all facial analysis algorithms, including face alignment, face recognition, face verification, and face parsing. Given an arbitrary image, the goal of face detection is to determine the presence of faces in the image and, if present, return the image location and extent of each face. While this appears as an effortless task for human, it is a very difficult task for computers. The challenges associated with face detection can be attributed to variations in pose, scale, facial expression, occlusion, and lighting condition. Face detection has made significant progress after the seminal work by Viola and Jones. Modern face detectors can easily detect near frontal faces and are widely used in real world applications, such as digital camera and electronic photo, album.

2.5.1 Different types of Face Detection

There are several face detection algorithms that are already present. The face detection algorithms can be subdivided in three categories. These categories are cascade based, DPM-based and neural network-based [18].

Cascade-Based The primary element of cascade based face detectors are haar-features. These haar-features are simple elements that describe how certain pixels are aligned. An array of haar-features describes how a feature can look like in a picture. Viola-Jones is the most well-known cascade based face detection algorithm [19].

DPM-based DPM stands for deformable parts model. This model is based on parts that construct a face based on their geometric position relative to each other. For example, a left eye (a part) needs to be left of a nose (another part). This model is robust against occlusion, because when a mouth and a nose is discovered in the right geometric place, then the algorithm can pretend that there are also eyes, even if the subject has sun glasses on [19].

Neural Network based These face detectors are based on self-learned features, where the DPM-based and Cascade-based face detectors have certain type of features that can be detected in an image, a neural network based face detector is free of these features. So, a neural network based face detector can learn new patterns and be more agile in difficult environments [19].

2.5.2 Viola-Jones Algorithm

The Viola-Jones face object detection frame work [20] is the first object detection framework to provide competitive object detection rates in real-time proposed in 2001 by Paul Viola and Michael Jones.

This algorithm is implemented in Open CV as cv Haar Detect Objects (). Viola-Jones face object detector become famous due to its open source implementation in the Open CV library. In order to find and trying to match from an object of an unknown size is usually adopted to work this field that possesses a high efficiency and accuracy to locate the face region in an image.

The Viola - Jones method for face object detection contains three techniques:

1. Integral image for feature extraction the Haar-like features is rectangular type that is obtained by integral image [20].
2. Adaboost is a machine-learning method for face detection [21], The word ―boosted‖ means that the classifiers at every stage of the cascade are complex themselves and they are built out of basic classifiers using one of four boosting techniques (weighted voting).
3. Cascade classifier used to combine many features efficiently. The word ―cascade‖ in the classifier name means that the resultant classifier consists of several [22].

Simpler classifiers (stages) that are applied subsequently to a region of interest until at some stage the candidate is rejected or all the stages are passed. Finally, the model can obtain the non-face region and face region after cascading each of strong classifiers.

2.5.2.1 Integral Image

The simple rectangular features of an image are calculated using an intermediate representation of an image, called the integral image. The integral image is an array containing the sums of the pixels‟ intensity values located directly to the left of a pixel and directly above the pixel at location (x,y) inclusive. So if A[x,y] is the original image and AI[x,y] is the integral image then the integral image is computed as $AI[x, y] = \sum A(x', y')$ [21][22].

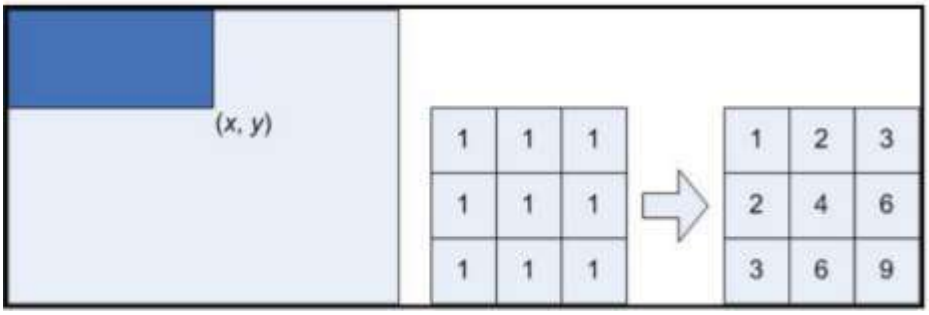

Figure 2.4: Integral image generation. The shaded region represents the sum of the pixels up to position (x,y) of the image. It shows a 3x3 image and its integral image representation.

2.5.2.2 Cascade

The Viola and Jones face detection algorithm eliminates face candidates quickly using a cascade of stages. The cascade eliminates candidates by making stricter requirements in each stage with later stages being much more difficult for a candidate to pass. Candidates exit the cascade if they pass all stages or fail any stage. A face is detected if a candidate passes all stages [22].

2.5.2.3 Haar Cascade Classifiers

The core basis for Haar classifier object detection is the Haar-like features. These features, rather than using the intensity values of a pixel, use the change in contrast values between adjacent rectangular groups of pixels. The contrast variances between the pixel groups are used to determine

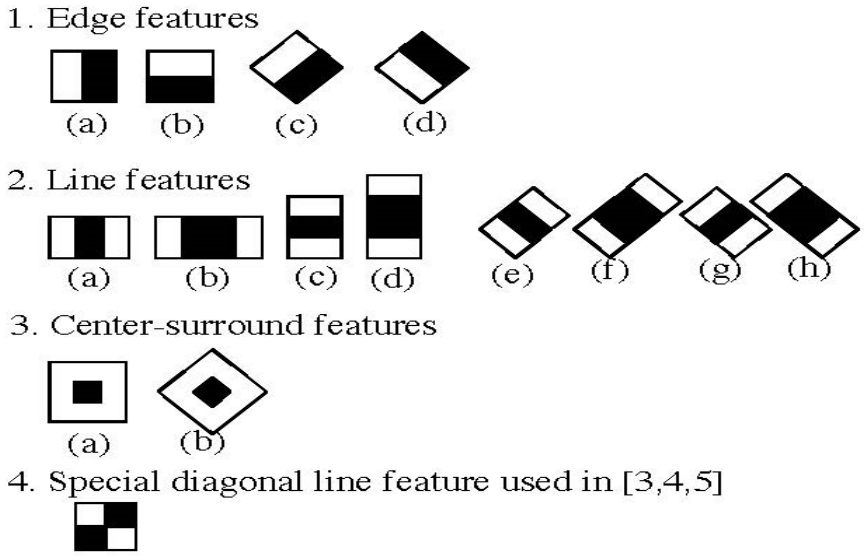

Figure 2.5: Common Haar-like features.

relative light and dark areas. Two or three adjacent groups with a relative contrast variance form a Haar-like feature.

2.5.2.4 AdaBoost

AdaBoost, short for "Adaptive Boosting", is a machine learning meta-algorithm formulated by Yoav Freund and Robert Schapire. It can be used in conjunction with many other types of learning algorithms to improve their performance. The output of the other learning algorithms ('weak learners') is combined into a weighted sum that represents the final output of the boosted classifier. AdaBoost is adaptive in the sense that subsequent weak learners are tweaked in favor of those instances misclassified by previous classifiers. AdaBoost is sensitive to noisy data and outliers. In some problems, however, it can be less susceptible to the overfitting problem than other learning algorithms. The individual learners can be weak, but as long as the performance of each one is slightly better than random guessing (e.g., their error rate is smaller than 0.5 for binary classification), the final model can be proven to converge to a strong learner, While every learning algorithm will tend to suit some problem types better than others, and will typically have many different parameters and configurations to be adjusted before achieving optimal performance on a dataset, AdaBoost (with decision trees as the weak learners) is often referred to as the best out-of-the-box classifier. When used with decision tree learning, information gathered at each stage of the AdaBoost algorithm about the relative 'hardness' of each training sample is fed into the tree growing algorithm such that later trees tend to focus on harder-to-classify examples.

2.5.2.5 Viola-Jones Face objects Detection Algorithm

Early efforts in face object detection have dated back as early as the beginning of the 1970s, where simple heuristic and anthropometric techniques [23] Face detection techniques can be categorized into two major groups that are feature based approaches and image based approaches. Image and video based approaches use linear subspace method, neural networks and statistical approaches for face object detection. Face feature based approaches can be subdivided into low level and high level analysis, feature analysis and active shape model analysis. Face detection is controlled by special trained scanning window classifiers Viola-Jones Face Detection Algorithm is the first real-time face detection system.

2.6 Face Recognition

Face is one of the most important visual object in our life which playing a major role in conveying identity and emotion and includes rich information. Face recognition is a huge research area in computer vision, pattern recognition and plays a vital role in the applications of image processing. Recognition or classification is to choose the available measure method such as Euclidean distance, which is used to classify the feature of images present in the database and test image [24]. The ability to recognize human faces is a demonstration of incredible human intelligence. Over the last three decades, researchers have been making attempts to study this outstanding visual perception of human beings in machine recognition of faces. Basically Face Recognition is the process through which a person is identified by his facial image. With the help of this technique it is possible to use the facial image of a person to authenticate him into any secure system.

2.6.1 Steps of Face Recognition

Typical structures of face recognition system consist of three major steps, acquisition of face data, extracting face feature and recognition of face. Figure-9 shows typical structure of face recognition system in which subject under consideration given to the system for the recognition purpose this is consider to be acquisition of face image. Later on feature is extracted from the image and finally it is given for the recognition purpose. These steps are elaborated as follow [25].

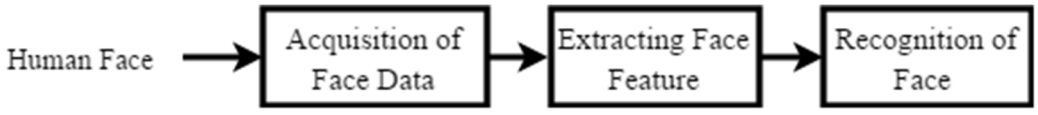

Figure 2.6: Face Recognition System

2.6.1.1 Acquisition of Face Data

Acquisition and Processing of Face Data is first step in the face recognition system. In this step face images are collected from different sources. The sources may be camera or readily available face image database on the website. The collected face images should have the pose, illumination and expression etc. variation in order to check the performance of the face recognition system

under these conditions. Processing of face database require sometimes otherwise causes serious effect on the performance of face recognition systems due changes in the illumination condition, background, lighting conditions, camera distance, and thus the size and orientation of the head. Therefore, input image is normalized and some image transformation methods apply on the input image [26].

2.6.1.2 Extracting Face Feature

Feature extraction process can be defined as the process of extracting relevant information from a face image. In feature extraction, a mathematical representation of original image called a biometric template or biometric reference is generated, which is stored in the database and will form the basis (vector) of any recognition task. Later these extracted features used in recognition. A greyscale pixel is considered as initial feature.

2.6.1.3 Recognition of Face

Once the features are extracted and selected, the next step is to classify the image. Appearance based face recognition algorithms use a wide variety of classification methods Such as PCA, LDA. In classification the similarity between faces from the same individual and different individuals after all the face images in database are represented with relevant features. Sometimes feature extraction & recognition process done simultaneously.

2.6.2 Fisher's Linear Discriminant Based Face Recognition

Fisher's linear discriminant (FLD) has recently emerged as a more efficient approach for extracting features for many pattern classification problems as compared to traditional PCA. FLD produces well separated classes in a low dimensional subspace, even under severe variation of rotating and noisy expressions [27]. The Eigenface technique, another method based on linearly projecting the image space to a low dimensional subspace, has similar computational requirements. An experimental analysis on the performances of FLD and traditional PCA were performed in tackling noise and rotation in face recognition problem with the face database. The experimental results show that FLD outperforms the traditional PCA on the basis of robustness. Fisherface is one of

the efficient face recognition methods. However, Fisherface requires several training images for each face, so it cannot be applied to the face recognition applications where only one example image per person is available for training [28], [29].

FLD is an example of a class specific method, in the sense that it tries to shape the scatter in order to make it more reliable for classification. This method selects W in such a way that the ratio of the between-class scatter and the within class scatter is maximized.

Let the between-class scatter matrix be defined as:

$$S_B = \sum_{i=1}^{c} N_i (\mu_i - \mu)(\mu_i - \mu)^T \quad \text{(2.1)}$$

and the within-class scatter matrix be defined as:

$$S_w = \sum_{i=1}^{c} (X_k - \mu_i)(X_k - \mu_i)^T \quad \text{(2.2)}$$

where μi is the mean image of class X_i, and N_i is the number of samples in class X_i . If S_w is nonsingular, the optimal projection W_{opt} is chosen as the matrix with orthonormal columns which maximizes the ratio of the determinant of the between-class scatter matrix of the projected samples to the determinant of the within-class scatter matrix of the projected samples, i.e.,

$$W_{opt} = \arg\max \left| W^T S_B^W \right| / \left| W^T S_W^W \right| = [w_1, w_2, \ldots w_m] \quad \text{(2.3)}$$

where $\{W_i \mid i=1, 2\ldots\ldots, m\}$ is the set of generalized eigenvectors of S_B and S_w corresponding to the m largest generalized eigenvalue $\{\lambda_i \mid i = 1,2,\ldots\ldots m.\}$ i.e., $S_B W_i = \lambda_i S_W W_i$, $i = 1,2,\ldots\ldots m$. There are at most c - 1 nonzero generalized eigenvalues and so an upper bound on m is c - 1, where c is the number of classes [29].

2.6.2.1 Basic Steps Employed in FLD

Step 1: The ratio of between-class and within-class scatter matrices is calculated.
Step 2: The eigenvectors of this matrix are then taken to formulate the projection matrix.
Step 3: The low dimensional sub-space created maximizes between-class scatter, while minimizing within-class scatter.

2.6.2.2 Fisherfaces Algorithm for FLD

1. A Fisherfaces algorithm uses classes of images instead of just single images. A class in this instance is a type of object, for instance a barrel, a pizza, or a strawberry.
2. The system is trained with multiple images from each class, creating Eigenvectors similar to Eigenfaces, but attempts to maximize the differences between classes while minimizing differences within classes.
3. Classes are then projected into this space by projecting each image of the class and taking the average
4. Input images can then be projected into Fisher space and compared to the average class projections.

The recognition of the images is better for FLD (fisherface) than PCA (eigenface) based algorithm. FLD is similar to PCA but with improvement in better classification of different classes image. With FLD, the training set could be classified to deal with different people. Accuracy could has been better in the basis of noise and rotation than PCA approach. Besides, FLD removes the first three principal components. FLD is more complex than PCA in finding the projection of face space. Calculation of ratio of between-class scatter to within-class scatter requires a lot of processing time. Besides, due to the need of better classification, the dimension of projection in face space is not as compact as PCA, results in larger storage of the face and more processing time in recognition. While PCA maximizes for all the scatter as appropriate for signal representation, FLD differentiates between the within class scatter and between-class scatter as appropriate for pattern classification [30].

2.6 Hardware and Software

For implementation we need pc, camera, GSM Modem as hardware and MATLAB, android studio as software.

2.7.1 GSM Modem

A GSM modem is a specialized type of modem which accepts a SIM card, and operates over a subscription to a mobile operator, just like a mobile phone. From the mobile operator perspective,

a GSM modem looks just like a mobile phone. When a GSM modem is connected to a computer, this allows the computer to use the GSM modem to communicate over the mobile network. While these GSM modems are most frequently used to provide mobile internet connectivity, many of them can also be used for sending and receiving SMS and MMS messages [31].

A GSM modem can be a dedicated modem device with a serial, USB or Bluetooth connection, or it can be a mobile phone that provides GSM modem capabilities. We have used Huawei E173 GSM Modem. Fig 2.7-shows the Huawei E173 GSM Modem.

Figure 2.7: Huawei E173 [32]

2.7.2 MATLAB R2014b

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non interactive language such as C or Fortran. It's a productive software. we want to use it for face recognition technique.

The name MATLAB stands for matrix laboratory. MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects, which together represent the state-of-the-art in software for matrix computation.

2.7.3 Android Studio 2.1.2

Android Studio is the official Integrated Development Environment (IDE) for Android app development, based on IntelliJ IDEA. On top of IntelliJ's powerful code editor and developer tools, Android Studio offers even more features that enhance your productivity when building Android

apps, such as: A flexible Gradle-based build system,, A fast and feature-rich emulator, A unified environment where you can develop for all Android devices, Instant Run to push changes to your running app without building a new APK, C++ and NDK support, Built-in support for Google Cloud Platform, making it easy to integrate Google Cloud Messaging and App Engine. We want to use android studio 2.1 for smart phone application.

2.8 Conclusion

In this chapter, some theoretical background of this thesis are discussed elaborately. Basic concepts of IoT, automated system, smart home environment, face detection, recognition, required hardware and software is presented in this section. Moreover, the advantages of human monitoring automated system in smart home environment using face recognition is discussed shortly. Some related works of this thesis and problem of existing system is described in the chapter 3.

Chapter III

Existing Systems and Problems

3.1 Introduction

Automated visitor monitoring system using GSM technology is very challenging problem in Smart home security system. There are many techniques for solving that problems. Some recent research on it have been discussed in last chapter. However, there are some limitations and problems exist in those systems. In this chapter, some existing problems will be discussed briefly.

3.2 Related Works

There are some mentionable research works on automated human monitoring system in smart home environment using face recognition approach. Some of these works are described below.

3.2.1 A Smart Visitors' Notification System with Automatic Secure Door Lock using Mobile Communication Technology

This paper presents the development of an automated security system to automate the entry of visitors, providing more flexibility of managing their record and securing homes or workplaces. Face recognition is part of this system to authenticate the visitors. A cost effective and SMS based door security module has been developed and integrated with the GSM network and made part of this system to allow communication between system and owner. This system functions in real time as when the visitor's arrived it will detect and recognizes his face and on the result of face recognition process it will open the door for authorized visitors or notifies and allows the owner's to take further action in case of unauthorized visitor. The proposed system is developed and it is successfully ensuring security, managing records and operating gate without physical interaction of owner [33].

3.2.2 Android Based Home Automation and Vision Surveillance Using Raspberry PI

In research [34] they aim at controlling Home appliances and visually monitor the home, via Android device using Internet as communication protocol (provides worldwide accessibility), Raspberry Pi as server system and Infra-red camera for surveillance. In their system user will be notified through android device when motion is detected in surveillance area. They create a user

friendly interface for the android device that allows the user to communicate with the Raspberry Pi server. The server will be interfaced with a relay circuit board that controls the appliances running in. Home and it is also connected to an Infra-Red Camera to provide surveillance. By this they offer a scalable and cost effective Home automation and surveillance system.

3.2.3 Development of an IoT-based visitor detection system

Hyoung-Ro Lee et al. proposed an IoT-based visitor detection system. It uses an IR sensor to detect human body and two ultrasonic sensors to locate visitor servo motor under the position. When a visitor is detected it drives camera module to locate the visitor. Recoded video and sensor data are stored in the Database. Saved data can see via the PC and Smart device. We developed the system using Raspberry Pi2 and sensor modules to verify the concept. It can track the visitor moving route and minimize the blind spots of the camera. And sensor data and recoded video are checked internet possible all remote location [35].

3.2.4 Face Identification in Smart Car Security System in Real Time

Sabitha tamilanjani et al. implement the project that offer advance security system in car, which consist of a face detection system, a GPS module, a GSM module and a control platform. The system is mainly used to identify the car and the thief who theft the car. FDS (Face Detection System) is used to detect the face of the driver and compare it with the port folio. The GSM plays an important role in this system. When the owner detects that his car was lost. Then immediately he can transfer the message from his mobile with the specified SIM which is predefined in the car module. The control depends upon the message received. The owner can able to perform door locking, car stopping, and alarm generation through his message from his mobile. The GPS module in the car detects the location of the car when the stop comment is passed from the owner and transfers location as longitude and latitude information along with the operation performance acknowledgment. For each message the reply is transferred after completion of specified control operation, for example if the GPS in car receives the message as! STOP then it stops the car and transfers the message to the owner as the stop is succeeded along with longitude and latitude information. So by this system the detection of thief image and the location of the car are simply smart and cheaper than traditional one [36].

3.2.5 Automated Security System using Surveillance

This paper is introduced by P.Vigneswari that represent "Automated security system using surveillance" uses raspberry pi board which itself acts as a mini computer. Whenever a person enters into the room, the fans and light will automatically switch on. At the same time camera is also switched on and it takes the image of the person who has interrupted. The user is alerted by sending an SMS with the link using GSM modem. The image can be viewed by clicking on this link. In the absence of a person the fans and lights will automatically be switched off [37].

3.2.6 Automatic Door Access System Using Face Recognition

This paper is comprised mainly of three subsystems: namely face detection, face recognition and automatic door access control. Face detection is the process of detecting the region of face in an image. The face is detected by using the Viola-Jones method and face recognition is implemented by using the Principal Component Analysis (PCA). Face Recognition based on PCA is generally referred to as the use of Eigenfaces.If a face is recognized, it is known, else it is unknown. The door will open automatically for the known person due to the command of the microcontroller. On the other hand, alarm will ring for the unknown person. Since PCA reduces the dimensions of face images without losing important features, facial images for many persons can be stored in the database. Although many training images are used, computational efficiency cannot be decreased significantly. Therefore, face recognition using PCA can be more useful for door security system than other face recognition schemes [38].

3.2.7 Child monitoring system

A child monitoring system is proposed by Helena C Silva for supervising a child from a remote location. The system includes a child-observation unit and a device for controlling the child-observation unit from a remote location [39].

3.2.8 Anti-Theft Mechanism through Face Recognition

This system is proposed by Neha J. Agrawal et al. The purpose of this Embedded Car Security System captures the image using a camera which will be hidden in the dash board. Face Detection Algorithm is used to detect the face. A database is created by taking the pictures of all the family members. A minimum of ten photos of each family member is taken. This captured image is

compared with the already present database using PCA algorithm. Once the captured face matches with the already present database a message is sent to the owner of the vehicle stating "Match Found". Otherwise, if the captured face does not match with the database then the processor activates the GPS module and the GSM module. Using the GPS module, the location of the vehicle is found out. This location is sent through the GSM module to the owner of the vehicle. Also along with the location, the image of the driver is sent through MMS to the owner [40].

3.2.9 An Efficient Approach of Face Detection and Recognition from Digital Images for Modern Security and Office Hour Attendance System

The purpose of this project is to make an efficient security system for university safety measurement which can also be used to calculate the office hours of Student Tutors by face detection and recognition. By using surveillance cameras, attached at all the entrance of university main buildings, the system can detect human faces and then it can recognize people. First, the system captures the image of a person who enters into the building and then detects the face from the image. Then the recognition system matches that image with the given database of images with valid information. After matching that image if the system recognize that face it gives a green signal to allow that person. Otherwise, if the system cannot recognize that face it gives an alert signal to block that person as an intruder. Also, this system calculates the office hours of the Student Tutors. By using face recognition, the system takes the starting time and ending time of the Student Tutors individually and then gives the result as output by calculating the time duration [22].

3.2.10 Web-based online embedded door access control and home security system based on face recognition

This paper concentrated about the implementation and deployment of wireless control system and accessibility in to a home environment for authenticated people only developed by Mrutyunjaya Sahani et al.. A wireless network technique ZigBee based and image processing technique PCA based, dedicatedly make the security system alive as per the request. ZigBee module and electromagnetic door lock module combined operate the door accessibility, has been designed and developed. Face detection and recognition algorithms, as well as a wireless interface are used to

detect and identify visitors and send an email and/or an alert message about the current home environment status via GSM network automatically to the home owner's mobile phone or any communication devices. The concerned authority can control the system through his/her mobile phone or any communication devices by sending AT Commands to GSM MODEM or by taking necessary actions for authentication through email, which is again password protected. Users can monitor visitors and control the door lock on active Web pages enhanced with JavaScript and HTML. This system finds a wide application in areas where physical presence is not possible all the time. The entire control system is built using ARM1176JZF-S microcontroller and tested for actual use in home environment [41].

3.3 Description of Problems

Security and well-being are two top concerns weighing on the minds of people in today's modern society. It's a challenging problem it can't be solved easily. The most important part of any home security system is accurately identifying visitor who enter and leave through the door. Several system has been invented for home security as discussed in related works in chapter II. Main problem is all the system Just concern about people not their arrival and departure time. They just secure the door or checking the suspected intruder inside and outside of home. They don't give much attention on child or family members with whom they interact daily. The existing systems are just notifying owner by a SMS, they do not make any application that help guardian to monitor or checking visitors at any time [33] [35] [37]. Our system tried to cover all this existing problem.

3.4 Conclusion

In this chapter, some limitations and problems of existing systems are pointed briefly. Motivated by these problems, a new approach for visitor monitoring system discussed in chapter 4. We hope that the new proposed method can overcome the existing problems successfully.

Chapter IV

Methodology

4.1 Introduction

In this chapter, the working principle and architecture of the proposed system will be discussed. We have represented our problem as a directed weighted graph. Initially a camera is on it will capture images and send it to the connected computer. After image processing on computer the output will be send to a smartphone through GSM modem After the experiment, a comparative study among these systems are shown that will be discussed in chapter V.

In the following section 4.2 and section 4.3, the architecture and the methodology of the proposed system are illustrated respectively.

4.2 System Architecture

Figure-4.1 shows the basic architecture of the proposed system. A person reaches at the entrance the camera will capture his image, captured image will be then processed on computer. After identification by computer program a SMS with time will be send via GSM modem to smart phone.

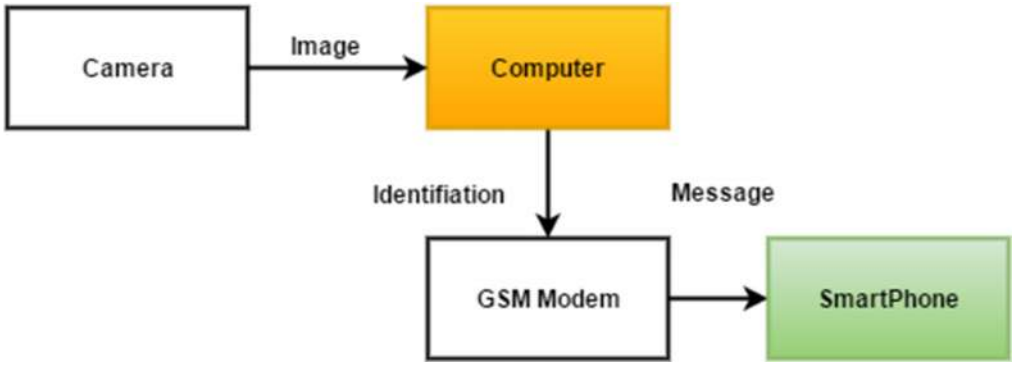

Figure 4.1: A Simple System Architecture.

Figure-4.2 shows the main system architecture of the proposed system. That is discussed briefly in below:

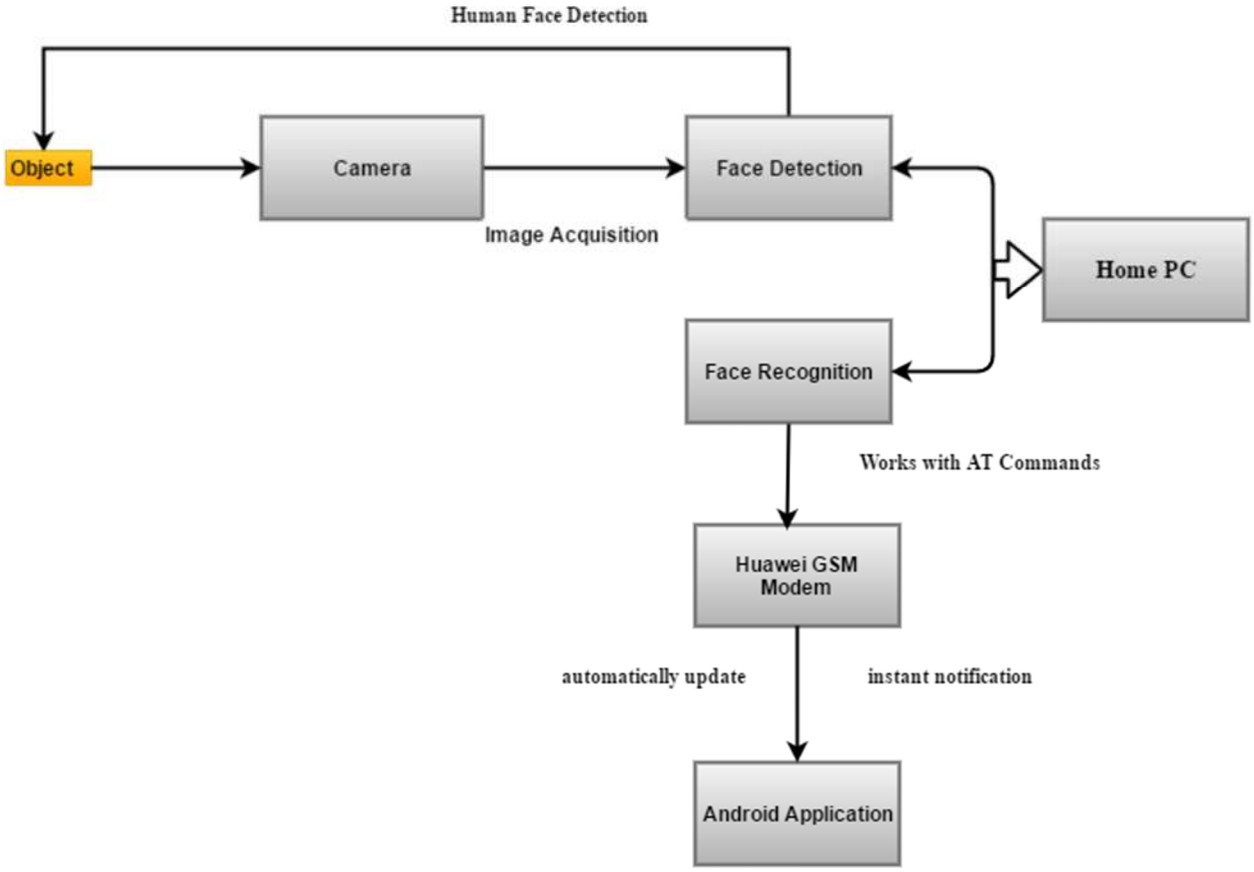

Figure 4.2: System Architecture.

4.2.1 Face Detection

The acquired image is processed to detect the face using the Viola-Jones algorithm (Viola and Jones, 2002) which effectively uses the cascade object detection. The cascade detector detects the face of the acquired image and the face region is extracted. The authentication based security system has the database which stores the face images of the authorized persons under different environments. The face images are enhanced by normalizing them to remove the unwanted information due to illumination constraints while acquiring the image and are stored in the database. Now the task of face recognition must be performed with the detected faces.

4.2.2 Face Recognition

In this paper, our training set consists of known face images of family members. Thus, the function of the face recognizer is to find the most similar average face vector among the training set to the average face vector of a given test image. Here, we want to identify the person entering and leaving home by comparing with the image database (test image) given to the system.

Here we use Fisher's linear discriminant (FLD) algorithm generally Linear Discriminant Analysis (LDA) to determine the most discriminating features between images of faces for light invariant and better classification of faces. Using FLD algorithm the calculations of the "within scatter matrix" and the "between scatter matrix" are performed to obtain the projected fisher images that are used in recognition (Welling, 2005; Tucker et al., 1997; Mika et al., 1999). Finally, the minimum Euclidean distance using min function is computed. The corresponding index with the minimum distance is the recognized image from database folder. By using Euclidian distance between threshold values of authorized and unauthorized faces corresponding images are compared and persons will be identified accordingly.

Here the implementation of FLD algorithm follows the following steps:

1. Get database set of images and then find mean of the images from total number of training images.
2. Find the difference between mean image and each of database images for calculating the deviation of each image from mean image.
3. Then sorting and eliminating small eigenvalues for calculating the eigenvectors of covariance matrix from centered image vectors.
4. Calculating covariance matrix using Snapshot method of Eigenface algorithm.
5. Calculating the mean of each class in Eigen-space.
6. Find Fisher discriminant basis's to maximize the Between Scatter Matrix, while minimizing the Within Scatter Matrix.
7. Eliminating zero eigens and sorting in descend order.

8. Projecting images onto Fisher linear space.
9. Extracting the FLD features from test image.
10. Calculating Euclidean distances between the projected test image and the projection of all centered training images are calculated. Test image is supposed to have minimum distance with its corresponding image in the training database.
11. If this distance is less than threshold then test image is considered to be in database and hence authorized, otherwise unauthorized.

4.2.3 Texting and Managing Android Application

When an intruder recognized as known or unknown then the system will automatically send a notification SMS using AT commands indicating someone's arrival or departure at home. Here, after the compilation of recognition method at MATLAB then a function called messageSends() haven been executed to send the message by compiling 'AT+CMGS' commands to a defined number. Then, it'll confirm the device to by executing 'AT+CMGF=1' command whether device SIM is OK or not. Yes, of course the SIM operator will charge the regular rate for messaging.

4.3 Steps of the System

It is the responsibility of the Guardian to know what their family members are up to. However, it'll be difficult to know how much privacy should be given to their children and where they should draw the line for those parents whose children have stepped into teenage hood.

Here, our system may suggest a solution to the parents. First we're using surveillance cameras attached at all the entrance of home. The system captures the image of a person who steps into and then the recognition system matches that image with the given database of images with valid information by using PCA face recognition algorithm. After matching that image if the system recognize that face it gives a text to the system holder using GSM modem. If it fails to recognize the incoming people, then it will also send the notification to the parent as unknown people arrival. Here, this system calculates the time his or her child stay away from home.

Figure 4.3 shows a flow chart of our system. The steps of the flowcharts are:

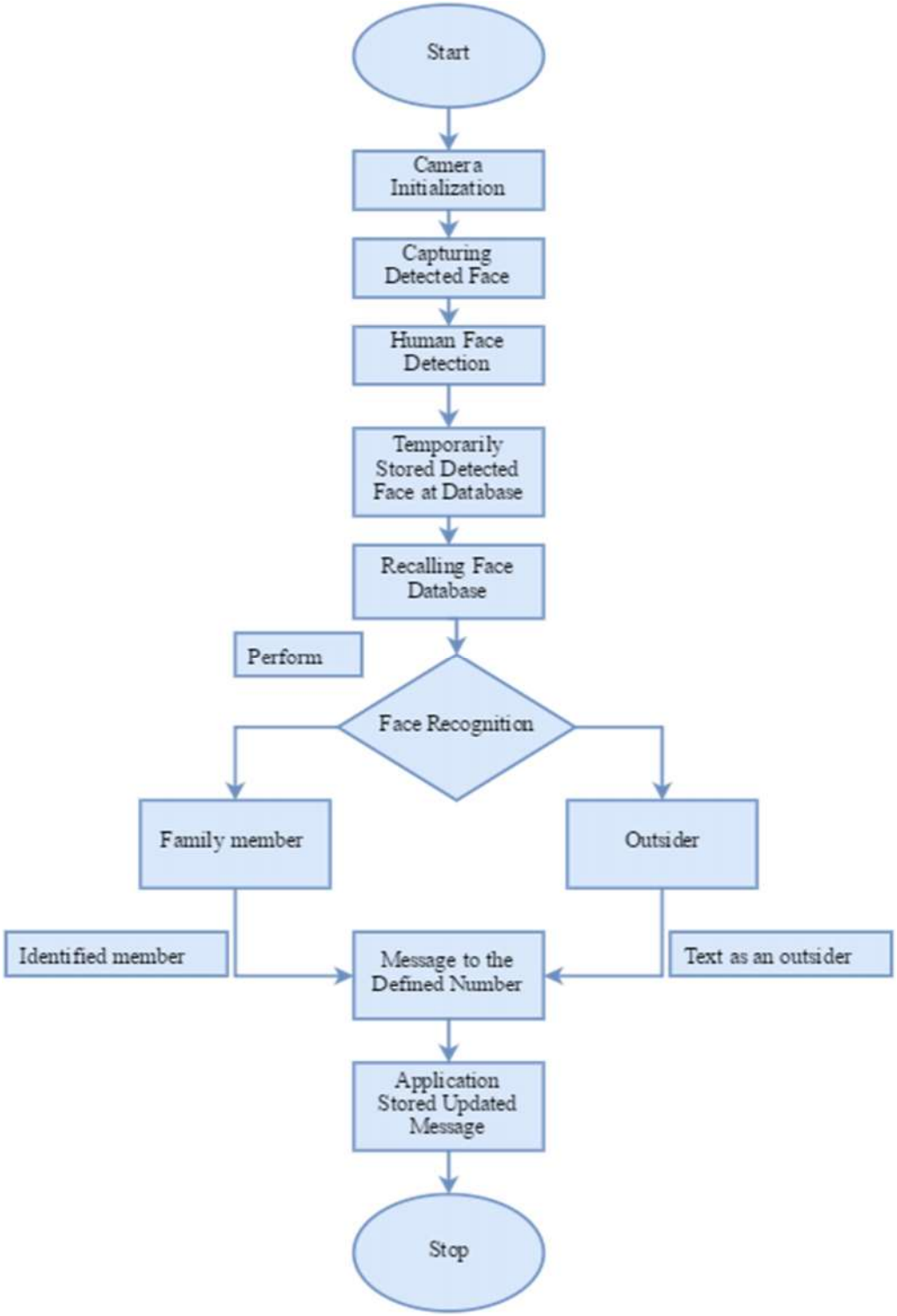

Figure 4.3: A Flowchart of the System

Step 1: Camera Initialization

Camera initialization will be done on this step. The camera will always be on. It connected to a pc. It consumes power from pc. So the pc should be on for the activation of camera. A MATLAB program will run on the pc. The camera is now ready to capture images.

Step 2: Capturing Images

After camera initialization it's ready to capture image. In this step images are captured whenever a person reaches at the entrance.

Step 3: Human Face Detection

From the capturing images step image will be send to the pc. Viola-Jones algorithm is used to detect the human faces from the images. So the faces will be detected on this step and send it to next step.

Step 4: Temporarily Stored Detected Face at Database

At this stage, Detected faces from the step 4 will be stored temporarily at computer face database.

Step 5: Recalling Face Database

At this step face database that was created in step 5 will be recalled for face recognition.

Step 6: Face Recognized?

This process is done by FLD algorithm. If the face is recognized as one of family member it will produce a message as output. Again if the face is not recognized as one of family member it will also produce a message as output.

Step 7: Message to the Defined number.

At this stage message produces from the step 7 will be send to a specific mobile number via GSM modem that connected to a pc.

Step 8: Application Stored Updated Message

The message come from the step 8 will be stored as an android application.

4.4 Challenges

- The main challenge of our research is getting accurate time of a visitor's arrival and departure.
- Another challenge of our research is detecting and representing human faces in such a way that the system can easily proceed for the next step and does not stuck.

4.5 Conclusion

In this chapter, we have projected on the system architecture of our system and the methodology to acquire the objectives. We have also discussed on some challenges that we may have to face in this research. We hope that our proposed method will overcome the existing problems and successfully acquire the main objectives of our research.

Chapter V

Experimental Results and Analysis

5.1 Introduction

In this paper, automatic visitor monitoring system using face recognition and detection is presented. Automatic face detection and recognition is done by Matlab program on PC. Computer is used to control the system depending on the incoming data sent from the surveillance camera. The prototype has been automatically sends text messages to the owner when an outsider is recognized. The software design has constructed and developed to allow the owner or parents to receive notifications for someone's arrival via smart device more specifically through android phone.

5.2 Implementation

Viola-Jones face detection method is used to detect the location of the face in an image. Since this detection method can detect only face images for frontal view correctly, this system has limitations in head orientation. For face recognition, FLD method is used to extract the important features of facial images. Since this method reduces the dimension of the dataset, this system can detect and recognize an image within one second. Therefore, this system can be used in automatic verification of people to improve smart home security for strangers without imposing security guards and wasting too many time.

Our database of images holds the following properties:

i. We have tested 120 faces of images (Train Database).
ii. There every training and testing images has 320*240 dimensions of pixels.
iii. We've stored and tested RGB real faces of images.

Figure-5.1 shows that

i. A visitor has arrived; the fast image of the following figure indicates that (1st image).

ii. The camera has captured the image of the visitor (2nd image).

iii. Viola-Jones detection algorithm has been detected human face from Captured image (red rectangle box of 3rd image).

iv. Detected face has saved to test database (4th image).

v. Then the system has been automatically compared with the training database of images and recognized the visitor (5th image with due notification).

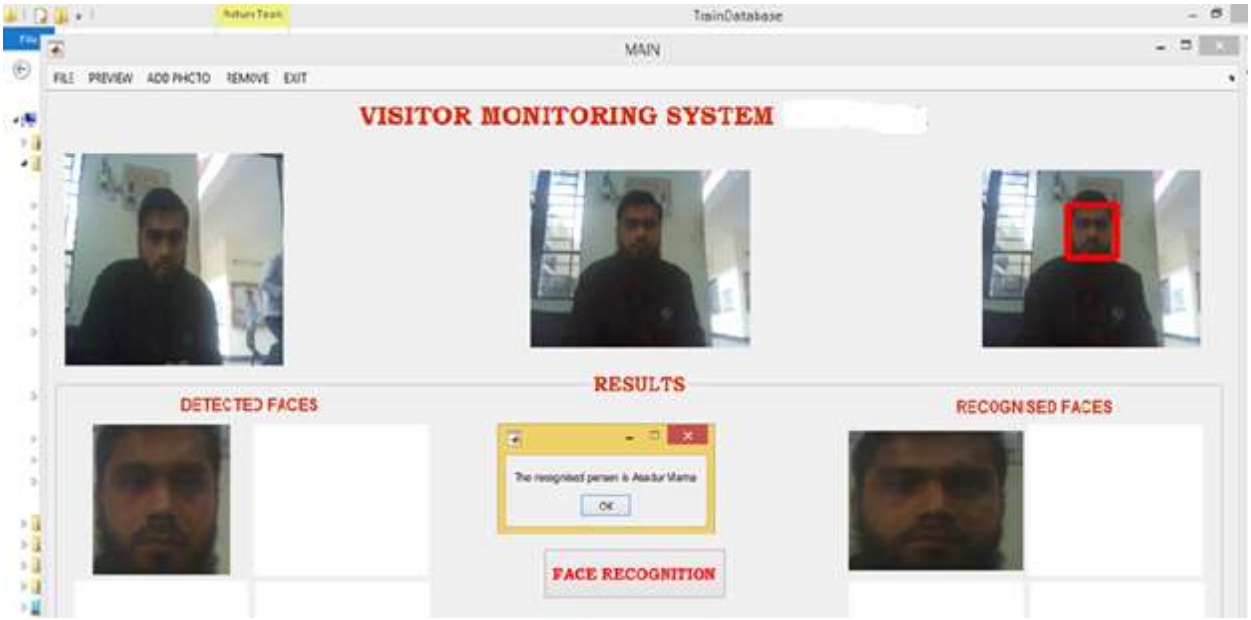

Figure 5.1: Experimental Partial Result (Random test)

Figure 5.2 and **Figure 5.3** shows that:

i. The above information of visitor's recognition has been send to specific contact number with arrival time (Figure 5.2).

ii. Android app which was previously install, hold the updated arrival notification message.

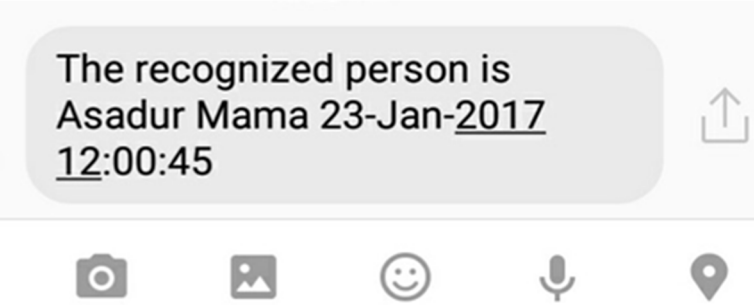

Figure 5.2 : Instant Notification.

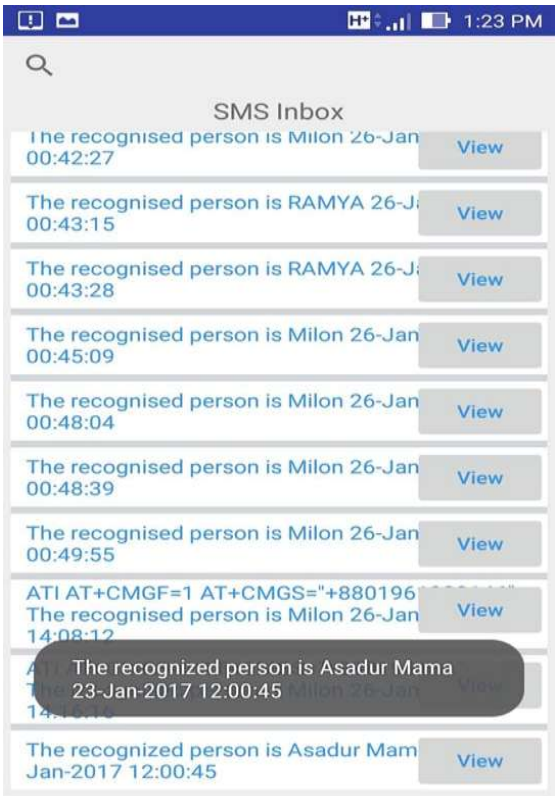

Figure 5.3: Android application.

5.2.1 Results Analysis

Here, the result analysis of the system:

Table-5.1: Result Analysis Table.

Test type	No. of Input Images	Successful	Accuracy
Recognition	230	215	93.47%
Message Sending	56	50	89.28%

According to the above Table-5.1, we've tested on 230 number of images, there 215 faces have been successfully recognized with the Fisher's linear discriminant algorithm with an accuracy of 93.47%. Again, we've also took 56 number of images as sample input for whole system operation from recognition to message sending where 50 instant messages have successfully reached to the desired phone number. So the accuracy would be 89.28%. Here, the accuracy has been slightly dropped for the lack of consistent network of Bangladeshi SIM operator.

5.2.2 Cost Analysis

Here, the approximate cost according to local market:

Table 5.2: Cost Analysis Table.

Equipment	**Price(Tk.)**
Computer	30,000
Camera (Live Acquisition Tool)	1,500
Huawei E173	1,500
Smartphone	4,000
	Total = 37,000

5.3 Comparison

Our system has brought automation to smart home platform with reposing daily life experience. However, we've compared our system with an IEEE publisher based SoC Design Conference (ISOCC) paper where H.-R. Lee, C.-H. Lin, and W.-J. Kim, titled "Development of an IoT-based visitor detection system" [35]:

Table-5.3: Comparison Table.

Our System	**Existing System**
1. Human face detected by Viola-Jones Algorithm. 2. Human face captured and recognized by FLD with Eigenface. 3. Recognized information will automatically send to home owner with arrival time. 4. Instant notification by SMS and an android application. 5. Unrecognized person information also stored in database for further inquiry.	1. IR sensor detects Human Body. 2. Human body captured by camera using Ultrasonic Sensor. 3. Captured images uploaded on open access web server.

5.4 Conclusion

In this chapter we have shown the experimental results of our proposed algorithm. The experimental results explain that our implemented system can easily perform better than some existing methods for monitoring visitors.

Chapter VI

Conclusions and Future Plan

6.1 Conclusions

In this thesis, we've explained the proposed methodology in detail that was designed for monitoring smart home environment for instant incoming and outgoing information of visitors with a reasonably good accuracy and running time. However, we've integrated an android device for home automation and surveillance to be more comfortable and feasible because of using mobile technology. A novel architecture for a home automation system is developed using the relatively new communication technologies.

This project would help to reduce the complexity and improve security, for outsider information, because the system automatically stored the images at the detection time. Therefore, Necessary action can be taken in a short span of time in case of an emergency. This, recognition based system is reliable to be used in other authorization applications involving robotics, border management, hospitals, banking security involving ATMs etc., which dramatically reduce the hazard of unauthorized entry.

As the prime concern of this thesis is dealing with uncertain intrusion at home and keep the parents in light about their children homecoming and outgoing. This is because, in most cases parents are busy in regular life struggle and fail to keen a concentration on relative or children. So our approach was to represent a novel methodology that can avoid this and meet the parents' requirements and build a bridge between family members.

6.2 Limitations and Future Plan

However, there're some limitations in our work, we've found out that the face detection module can't detect those faces not in front of camera, for example, when there is a big angle between face and the camera. It proves to us that the detection algorithm cannot detect all kinds of faces, and the camera need to be placed toward the front entrance where every incoming and outgoing can easily visible if possible.

By keeping similarity with the limitations of this thesis work, it can be said that the problem should be represented by using different methods existing tools. Besides, implementing the same methodology on real time we can

i. Present it as a complete security platform for entrance as well as insight of smart home, by detecting harmful object at entrance.
ii. Establish as a complete independent system by not linking with computer.

References

[1] J. Han, C.-S. Choi, and I. Lee, "More efficient home energy management system based on ZigBee communication and infrared remote controls," IEEE Transactions on Consumer Electronics, vol. 57, no. 1, pp. 85–89, Feb. 2011.

[2] H. Erdem and A. Uner, "A multi-channel remote controller for home and office appliances," IEEE Transactions on Consumer Electronics, vol. 55, no. 4, pp. 2184–2189, Nov. 2009.

[3] B. Yuksekkaya, A. A. Kayalar, M. B. Tosun, M. K. Ozcan, and A. Z. Alkar, "A GSM, internet and speech controlled wireless interactive home automation system," IEEE Transactions on Consumer Electronics, vol. 52, no. 3, pp. 837–843, Aug. 2006.

[4] C. Lien, Y. Bai, and M. Lin, "Remote-controllable power outlet system for home power management," IEEE Transactions on Consumer Electronics, vol. 53, no. 4, pp. 1634–1641, Nov. 2007.

[5] S. Vernon and S. S. Joshi, "Brain–Muscle–Computer interface: Mobile-phone prototype development and testing," IEEE Transactions on Information Technology in Biomedicine, vol. 15, no. 4, pp. 531–538, Jul. 2011.

[6] M. Faundez-Zanuy, "Are inkless fingerprint sensors suitable for mobile use?" IEEE Aerospace and Electronic Systems Magazine, vol. 19, no. 4, pp. 17–21, Apr. 2004.

[7] M. Faundez-Zanuy, "Technological evaluation of two AFIS systems," IEEE Aerospace and Electronic Systems Magazine, vol. 20, no. 4, pp. 13–17, Apr. 2005.

[8] M. Faundez-Zanuy, "Privacy issues on biometric systems," IEEE Aerospace and Electronic Systems Magazine, vol. 20, no. 2, pp. 13–15, Feb. 2005.

[9] A. C. Little, B. C. Jones, and L. M. DeBruine, "The many faces of research on face perception," Philosophical Transactions of the Royal Society B: Biological Sciences, vol. 366, no. 1571, pp. 1634–1637, May 2011.

[10] A. Meola, "What is the Internet of things (IoT)?" in Business Insider, Business Insider, 2016. [Online]. Available: http://www.businessinsider.com/what-is-the-internet-of-things-definition-2016-8. Accessed: Jan. 24, 2017.

[11] "Internet of things examples," 1999. [Online]. Available: http://www.postscapes.com/internet-of-things-examples/. Accessed: Jan. 24, 2017.

[12] Gianmarco De Francisci Morales, Albert Bifet, Latifur Khan, João Gama, Wei Fan: IoT Big Data Stream Mining. KDD 2016, p.p.2119-2120

[13] "Executive summary," 2016. Available: http://corporate.comcast.com/images/August_Xfinity-Safe-and-Secure-Study-Report.pdf. Accessed: Jan. 24, 2017.

[14] Credit, "What is an automated system?" in technology, Reference, 2017. [Online]. Available:https://www.reference.com/technology/automated-systemc85583d0f17a632, ©2017IAC Publishing, LLC. Accessed: Jan. 24, 2017.

[15] Priti Puri and Y. Jog, "Smart Home Environment-A Bibliometric Review," Vol. 7, No. 3, p.p. 9278–9284, Mar. 2016.

[16] F. Kausar, "Intelligent home monitoring using RSSI in wireless sensor networks," International journal of Computer Networks and Communications, vol. 4, no. 6, pp. 33–46, Nov. 2012.

[17] C.-C. Hsieh and J.-A. Lai, "Face mole detection, classification and application," Journal of Computers, vol. 10, no. 1, pp. 12–23, 2015.

[18] T. He, H. Mao, and Z. Yi, "Moving object recognition using multi-view three-dimensional convolutional neural networks," Neural Computing and Applications, Mar. 2016.

[19] K. Korekado, T. Morie, O. Nomura, T. Nakano, M. Matsugu, and A. Iwata, "Face position detection by a convolutional neural network using an image filtering processor VLSI," International Congress Series, vol. 1291, pp. 253–256, Jun. 2006.

[20] P.VIOLA and M.J.Jones, Robust real time face detection ,international journal of computer vision,57 (2004).

[21] K. T. Talele, S. Kadam, A. "Tikare, Efficient Face Detection using Adaboost", ―IJCA Proc on International Conference in Computational Intelligence‖, 2012.

[22] Phillip I.W.,Dr. John F. Facial Feature Detection Using Haar Classifiers,Jcsc 21, (2006).

[23] T. Sakai, M. Nagao, and T. Kanade, Computer analysis and classification of photographs of human faces,in Proc. First USA—Japan Computer Conference, , pp. 2-7, 1972.

[24] M. Kirby and L. Sirovich, "Application of the Karhunen-Loeve procedure for the characterization of human faces," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 12, no. 1, pp. 103–108, 1990.

[25] Z. H. Al-Tairi, R. W. Rahmat, M. I. Saripan, and P. S. Sulaiman, "Skin segmentation using YUV and RGB color spaces," Journal of Information Processing Systems, vol. 10, no. 2, pp. 283–299, Jun. 2014.

[26] D. Ghimire and J. Lee, "A robust face detection method based on skin color and edges," Journal of Information Processing Systems, vol. 9, no. 1, pp. 141–156, Mar. 2013.

[27] H. Kong, L. Wang and E. K. Teoh, J.G. Wang and V. Ronda, "A Framework of 2D Fisher Discriminant Analysis: Application to Face Recognition with Small Number of Training Samples", IEEE Conference on Computer Vision and Pattern Recognition (CVPR), pp. 1083-1088, 2005.

[28] Harmon, L.D., "The recognition of faces", Scientific American, Vol. 5, pp. 71-82, 1973.

[29] P. N. Belhumeur, J. Hespanda, and D. Kiregeman, "Eigenfaces vs. Fisherfaces: Recognition Using Class Specific Linear Projection", IEEE Trans. on PAMI, Vol. 19, No. 7, pp. 711-720, July 1999.

[30] M. Begum, M. Golam Moazzam, and M. Shorif Uddin, "Quantitative analysis on robustness of FLD and PCA-based face recognition Algorithms," International Journal of Computer Applications, vol. 99, no. 19, pp. 10–14, Aug. 2014.

[31] N. Wireless, "What is a GSM modem?"-2002. Available: https://www.nowsms.com/faq/what-is-a-gsm-modem. Accessed: Jan. 24, 2017.

[32] "Huawei E173 - 3G modem wiki," 2011. Available: http://www.3g-modem-wiki.com/page/Huawei+E173. Last Accessed: Jan. 24, 2017.

[33] Marwa Khalid and Sadia Majeed, "2016 A Smart Visitors' Notification System with Automatic Secure Door Lock using Mobile Communication Technology," IJCSNS International Journal of Computer Science and Network Security, vol. 2, no. 1, pp. 39–44, Feb. 2016.

[34] R. Senthil Kumar And Vigneshram, "Android Based Home Automation And Vision Surveillance Using Raspberry Pi," International Journal Of Computer Science And Engineering (IJCSE), Vol. 4, No. 2, Pp. 29–38, Mar. 2015.

[35] H.-R. Lee, C.-H. Lin, and W.-J. Kim, "Development of an IoT-based visitor detection system," 2016 International SoC Design Conference (ISOCC), Oct. 2016.

[36] V. Venkateswaran., "Intelligent Approach For Smart Car Parking Reservation And Security Maintenance System," International Journal Of Research In Engineering And Technology, Vol. 03, No. 02, Pp. 248–251, Feb. 2014.

[37] P. Vigneswari, R. R. Narmatha, and V. Indhu, "Automated Security System using Surveillance," , International Journal of Current Engineering and Technology, vol. 5, no. 2, Mar. 2015.

[38] N. SunitaDevi and K. Hemachandran, "Automatic face recognition system using pattern recognition techniques: A survey," International Journal of Computer Applications, vol. 83, no. 5, pp. 10–13, Dec. 2013.

[39] H. C. Silva, R. J. Babineau, and C. Management, Child monitoring system. Google Books, 2014. Available: https://www.google.com/patents/US20150079809. Last Accessed: Jan. 02, 2017.

[40] Neha J. Agrawal and Dr. Siddharth A. Ladhake, "Anti-Theft Mechanism through Face Recognition," International Journal of Advance Research in Computer Science and Management Studies, vol. 4, no. 5, pp. 244–252, May 2016.

[41] M. Sahani, C. Nanda, A. K. Sahu, and B. Pattnaik, "Web-based online embedded door access control and home security system based on face recognition," 2015 International Conference on Circuits, Power and Computing Technologies [ICCPCT-2015], Mar. 2015.