DUOGUARD- AUTHENTICATED LOCK FOR VISUALLY DISABLED

Capstone Project Report

End -Semester Evaluation

Submitted by:

102017112	**Khushi Goel**
102016100	**Ayush Nagpure**
102016041	**Asmi Lakhani**
102016056	**Nimit Gupta**
102196010	**Nitish Jaswal**

BE Fourth Year- CSE

CPG No.-23

Under the Mentorship of

Dr. Sushma Jain

(Associate Professor)

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

Computer Science and Engineering Department

Thapar Institute of Engineering and Technology, Patiala

December 2023

ABSTRACT

Visually impaired people face limitations in carrying out movements and their daily activities without assistance. There is no such secure lock that exists for blind people. So this project aims to build a two-factor secure lock that can be used independently by visually disabled people without any assistance. This 2-factor lock would first use face detection and then hand gestures to unlock the door. The image data from the camera will be fed to face recognition code and processing will be executed. This module will consist of a database of allowed faces with a blind person being the master with the ability to enter the gesture sequence. If the person is a master user then the system will generate a prompt along with an activation sound to enter the hand gestures. The hand gesture module will be able to recognize the hands of the person in front and a deep learning model will be trained to recognize gestures in sequence. Once the hand gestures match, a trigger signal will be sent to the latch module. The latch module upon receiving the trigger signal will open the latch and it closes automatically when the person enters the facility.

DECLARATION

We hereby declare that the design principles and working prototype model of the project entitled **DUOGUARD- Authenticated lock for visually disabled** is an authentic record of our own work carried out in the Computer Science and Engineering Department, TIET, Patiala, under the guidance of **Dr. Sushma Jain** during 7th semester (2023)

Roll No.	Name	Signature
102017112	Khushi Goel	Khushi goel
102016100	Ayush Nagpure	Ayush
102196010	Nitish Kumar	Nitish
102016056	Nimit Gupta	[illegible]
102016041	Asmi Lakhani	[illegible]

Counter Signed By:

(Dr. Sushma Jain)

Mentor: Dr. Sushma Jain

Associate Professor

Computer Science & Engineering Department
TIET, Patiala

ACKNOWLEDGEMENT

We would like to express our thanks to our mentor Dr. Sushma Jain. She has been of great help in our venture, and an indispensable resource of technical knowledge. She is truly an amazing mentor to have.

We are also thankful to **Dr. Shalini Batra,** Head of, Computer Science and Engineering Department, entire faculty and staff of Computer Science and Engineering Department, and also our friends who devoted their valuable time and helped us in all possible ways towards successful completion of this project. We thank all those who have contributed either directly or indirectly towards this project.

Lastly, we would also like to thank our families for their unyielding love and encouragement. They always wanted the best for us and we admire their determination and sacrifice.

Date: 19th December, 2023

Roll No.	**Name**	**Signature**
102017112	Khushi Goel	Khushi goel.
102016100	Ayush Nagpure	Ayush.
102196010	Nitish Kumar	Nitish
102016056	Nimit Gupta	[illegible]
102016041	Asmi Lakhani	[illegible]

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1. INTRODUCTION

1.1 Project Overview

Individuals with visual impairments encounter challenges in performing daily activities independently. To address this issue, a pioneering project is underway to develop a two-factor secure lock that empowers visually disabled individuals to unlock doors autonomously. The proposed system combines facial recognition and hand gesture technologies to create a seamless and accessible entry mechanism.

In the initial phase of this innovative project, a camera is employed to capture image data, which is then processed through a face detection algorithm. The core of this module includes a comprehensive database containing information about authorized faces. Notably, a visually impaired person takes on the role of a master user and can input a unique gesture sequence for authentication.

For master users, the system initiates an interactive prompt with an activation sound, signaling the need to enter specific hand gestures. This auditory feedback is crucial for guiding individuals through the process, enhancing the overall user experience, and ensuring accessibility. The subsequent step integrates a hand gesture recognition module designed to identify and validate the gestures performed by the individual facing the camera.

Deep learning is pivotal in training the model to recognize these hand gestures in a predefined sequence. Upon successfully matching the input gestures with the pre-established pattern, a trigger signal is transmitted to the latch module. This trigger signal is the key to unlocking the latch mechanism, enabling the individual to open the door effortlessly.The latch module, upon receiving the trigger signal, the seamless opening of the door latch, providing access to the person.

As this project unfolds, it seeks to not only provide a technological solution for independent access but also to redefine the possibilities for inclusivity and accessibility in the lives of visually impaired individuals. Through the integration of facial recognition and hand gestures, this two-factor secure lock system aims to empower users with a reliable and user-friendly solution tailored to their unique needs.

1.1.1 Technical Terminology

- **Raspberry Pi 3** - The Raspberry Pi 3 is a credit-card sized computer capable of doing just about anything a desktop PC does. The Pi is like a motherboard having all the required constituents which forms a great CPU.
- **OpenCV**- OpenCV is the huge open-source library for the computer vision, machine learning, and image processing and now it plays a major role in real-time operation which is very important in today's systems.
- **Machine Learning**: Machine learning is the scientific study of algorithms and statistical models that computer systems use to perform a specific task without using explicit instructions, relying on patterns and inference instead.
- **Deep Learning**: Deep learning is a subset of machine learning in artificial intelligence (AI) that has networks capable of learning unsupervised from data that is unstructured or unlabeled.
- **Measurement Science & Technology**: It encompasses the study dedicated to designing, maintaining, and enhancing measuring instruments within the realms of natural sciences and engineering. In our context, this discipline is applied through the utilization of IoT, leveraging interconnected devices for advanced measurement capabilities.
- **Data Analytics:** Data analysis is a systematic process encompassing the examination, purification, transformation, and modeling of data, aimed at uncovering valuable insights, facilitating informed conclusions, and bolstering effective decision-making for optimal outcomes. It involves employing various techniques to discern patterns, trends, and correlations within datasets, ultimately contributing to a deeper understanding of the underlying information.

1.1.2 Problem Statement

The traditional lock and key approach is impractical for individuals with visual disabilities, necessitating more inclusive and accessible alternatives. While automated systems like fingerprint and retina scanners exist, they pose challenges for visually disabled individuals as they often require external assistance. These solutions, though available, lack independence for users with visual impairments and fall short in terms of security.

Given these limitations, there is a critical need for a locking system that not only ensures security but also offers convenience for individuals with visual disabilities. Existing technologies, including fingerprint and retina scans, fail to provide a comprehensive solution that can be autonomously operated by those with visual impairments. Consequently, the development of a secure and user-friendly locking system tailored to the unique needs of visually disabled individuals becomes paramount. Such a system would bridge the accessibility gap, empowering individuals with visual disabilities to independently and confidently secure their spaces without compromising on security standards.

1.1.3 Goal

The main goal of this project is to make a two-factor lock that's really easy and handy for visually impaired folks. We want it to be super simple for them to use. Also, safety is a big worry for these people, so the lock has to be really secure. We're working on adding features that make it safe and reliable. Our aim is to create a lock that not only makes their daily life easier but also assures them that it's a safe and trustworthy solution. This way, we hope to give visually impaired individuals a practical and secure tool for their daily needs.

1.1.4 Solution

This innovative system employs face detection and hand gestures as the primary means of unlocking the door, catering especially to the needs of visually impaired individuals. The integration of a dedicated face recognition module and a hand gesture module forms the foundation of this intelligent lock. The camera captures image data, directing it to the face recognition code for processing. The face recognition module features a database of authorized faces, with the visually impaired person designated as the master user, endowed with the capability to establish a unique gesture sequence.

Upon identification as a master user, the system prompts the individual with an activation sound to initiate the hand gesture sequence. The hand gesture module, equipped with a deep learning model, discerns and validates gestures in a predefined sequence. When the hand gestures align with the established sequence, a trigger signal activates the latch module, opening the latch. Importantly, the latch automatically closes upon the person entering the facility, ensuring security and convenience.

In the scenario where the user's category is recognized but not as a master user, the sound module is engaged. This activates an announcement, verbally revealing the identity of the person at the door. This dual-layer authentication system, tailored for accessibility and security, represents a significant advancement in providing visually impaired individuals with an independent and effective means of securing their living spaces.

1.2 Need Analysis

According to a comprehensive report jointly issued by the World Health Organization (WHO) and the International Agency for Prevention of Blindness (IAPB), it has revealed that an estimated 285 million individuals worldwide grapple with visual impairments. The challenges these visually impaired individuals face extend beyond mere physical movement limitations, significantly impacting their ability to carry out daily activities independently. Astonishingly, nearly 90% of this demographic is compelled to rely on the assistance of others to ensure their safety, highlighting the pressing need for innovative solutions.

In light of these challenges, it becomes evident that existing security measures, such as locks, need to cater to the unique needs of the visually impaired adequately. It underscores the need to develop a specialized two-factor secure lock system for individuals with visual disabilities. The primary goal of this groundbreaking project is to empower visually impaired individuals to navigate their living spaces autonomously without being dependent on external assistance.

The envisioned two-factor secure lock seeks to address the vulnerability experienced by visually impaired individuals, allowing them to regulate and monitor access to their homes independently. By incorporating advanced features, this innovative lock not only enhances security but also offers a sense of empowerment to visually impaired individuals, allowing them to ascertain and control the identity of individuals at their doorstep. This heightened level of control ensures they can move freely within their residences without fearing unauthorized entry.

In essence, this project represents a pivotal step towards fostering inclusivity and independence for visually impaired individuals by leveraging technology to create solutions that align with their unique needs. The overarching aim is to alleviate the challenges associated with security and mobility, ultimately enhancing the quality of life for millions around the globe facing visual impairments.

1.3 Research Gaps

Table 1: Research Gaps

Research Gaps	Deficiencies in research	References
Difficulty in face detection and hand detection	If the color of the background matches that of skin then there is difficulty in detection of the face and that causes an error and the same goes for hand gesture recognition.	"Image-based Face Detection and Recognition"-by Faizan Ahmad, Anima Najam, and Zeeshan Ahmed "Hand Gesture Recognition Based on Computer Vision: A Review of Techniques"-by Munir Oudah, Ali Al-Naji, and Javaan Chahl
Accuracy of the face recognition model	The current face recognition models that exist, do not give very high accuracy.	"Design And Implementation Of Automated Door Accessing System With Face Recognition"-International Journal of Science and Modern Engineering(IJISME), Volume-1, Issue-12, November 2013.
Cost structure	The current locking systems are quite expensive and there is a need to develop cheaper systems that are affordable.	"Swing Door Lock comes with a blind-friendly mechanism"-homecrux.com
Speed and efficiency	The current sensors and systems are a little bit slow and take time to process.	"Raspberry Pi as the Internet of Things hardware: Performances and Constraints" by Vladimir Vujovic
Lighting issue	Proper lighting is required to recognize the face and hand gestures. Insufficient light can decrease the accuracy.	Study of Face Recognition Techniques: by Madan Lal, Kamlesh Kumar

1.4 Problem Definition and Scope

Visually impaired individuals confront multifaceted challenges, heavily relying on others for daily tasks and grappling with pervasive safety concerns. The prevailing fear surrounding the security of their homes and belongings underscores the urgent need for innovative solutions. Existing locking systems, ill-suited for independent use and lacking robust security features, exacerbate their vulnerability. This project responds to these pressing issues by developing a transformative 2-factor locking system explicitly tailored to the needs of the visually impaired.

The system begins with cutting-edge face detection technology, where a strategically positioned camera captures image data, initiating face recognition processing. Successfully identifying the user's face triggers the activation of a sophisticated hand gesture module—a deep learning-powered mechanism that authenticates specific gestures sequentially.

The deep learning model within the hand gesture module is meticulously trained to recognize various gestures, prioritizing flexibility and ease of use for visually impaired individuals. This dual-layer authentication process addresses safety concerns and stands as a testament to the project's commitment to fostering independence.

After completing the facial recognition and hand gesture authentication, a trigger signal is sent to the latch module, granting access. Crucially, the system features an automated closing mechanism, ensuring the door closes after the user enters the facility, reinforcing their safety and peace of mind.

By amalgamating cutting-edge technology, inclusivity, and advanced security measures, this 2-factor locking system seeks to redefine security for visually impaired individuals. The project represents a significant stride toward creating an environment where they can navigate their living spaces with confidence and autonomy, alleviating the constant apprehension that defines their daily experiences.

1.5 Assumptions and Constraints

As we know our project will not be able to cover all possible scenarios as our scale of work is very small. So we will be making some assumptions in our project to justify the functionality of our project. Also, our project will be restricted by some hardware, human, and technological constraints.

Table 2: Assumptions

S.No.	**Assumptions**
1.	It is assumed that the visually impaired user can navigate through the main door and house.
2.	It is assumed that the user has learned the hand gestures for the passcode.
3.	It is assumed that the user has sufficient hearing ability to listen to the voice output by the locking system and react accordingly.
4.	It is assumed that lighting is adequate for efficient image pre-processing.
5.	It is assumed that the ML model will have high accuracy and very little time delay.

Table 3: Constraints

S.No.	**Constraints**
1	The gesture sequence can be mimicked by another person standing beside the blind user.
2	Synchronization of dynamic gestures posed by the blind user with the camera frame rate is a challenge.

1.6 Standards

This section briefly discusses the standards used in the project.

IEEE

The Institute of Electrical and Electronics Engineers Standards Association (IEEE-SA) is an organization with IEEE that develops global standards in a broad range of industries, including power and energy, biomedical and health care, information technology and robotics, telecommunication and home automation, transportation, nanotechnology, information assurance and many more.

Industry 4.0

Industry 4.0 is the ongoing automation of traditional manufacturing and industrial practices, using modern smart technology. Large-scale machine-to- machine communication (M2M) and the internet of things (IoT) are integrated for increased automation, improved communication and self-monitoring, and production of smart machines that can analyze and diagnose issues without the need for human intervention

Web 2.0

Emphasize user-generated content, easy-to-use, participatory culture, and interoperability (i.e., compatible with other products, systems, and devices) for end-users. It Connects information sources using the model of the Web.

ISO

In the case of digital cameras, ISO sensitivity is a measure of the camera's ability to capture light. Digital cameras convert the light that falls on the image sensor into electrical signals for processing. ISO sensitivity is raised by amplifying the signal. Doubling ISO sensitivity doubles the electrical signal, halving the amount of light that needs to fall on the image sensor to achieve optimal exposure.

1.7 Approved Objectives

The proposed system seeks to meet the following proposed objectives:

1. To study about the problems and the needs associated with visually impaired people.
2. To develop a two factor authentication lock using two modules - face recognition and hand gesture recognition which will independently run on raspberry pi.
3. To use deep learning model to recognize gestures posed by a blind person and convert them sequentially into a unique passkey.
4. To create a safe and robust system for blind people which can be used by them independently without any assistance.

1.8 Methodology

The following methodology will be followed while working on the proposed system:

1. A proximity sensor will be used to detect the presence of a person in front of the lock. It will trigger a sound on the buzzer and activate the camera module.
2. A Face recognition module will be developed. The image data from the camera will be fed to face recognition code which will be deployed on a raspberry pi where the processing will be executed. This module will consist of a database of allowed faces with the blind person being the master user with the ability to enter the gesture lock. The master would be able to maintain a record of known faces on the database. Local storage shall be used for storing the images. Depending on the person in front of the camera the following possibilities will be incorporated:-
    a. If the person is the master user then the system will generate a prompt along with an activation sound to enter the hand gesture sequence as saved by the master.

   b. If the person has his/her face registered into the system, the module will identify the person and give a speech output recognizing the person.
   c. If the person falls into neither category, the sound module will generate a normal alarm.
3. A hand gesture recognition module will be developed. The module will store a passkey corresponding to the sequence of hand gestures as demonstrated by the master user. The passkey can be changed at will only by the master user. This module will consist of the following features:-
   a. The module will be able to recognize the hands of the person in front and apply background reduction on the images captured. Series of image processing techniques like erosion, dilation, and thresholding will be applied for this purpose.
   b. A deep learning model will be trained to recognize the gesture in the input image. The model will recognize gestures in a sequence.
   c. The system will maintain a stack of the gestures entered and convert it into a passkey. If the passkey matches with the accepted key, a trigger signal is sent to the latch module.
4. The latch module upon receiving the trigger signal will open the latch for 10s when the person can enter the facility and the latch will close automatically after that.
5. The user will be provided with an option to set and reset the password using a reset button on the latch. The blind user with the assistance of a technician can enter the security code entered on the latch initially. The user would be able to register himself/herself as a master user by capturing face images and subsequently entering a sequence of gestures as the new security key.
6. Additionally, our device enables the master user to store facial images of recognized individuals. These images are securely stored in a database, and advanced facial recognition techniques are employed for accurate identification. This feature enhances the system's personalization, allowing the master user to manage and control access for known faces.

7. The following framework will be followed during the development procedure of the proposed system:

    a. Backend - Python will be used for this purpose as it has proven to be very dynamic for developing applications in a short period using a plethora of open source libraries that come with it.
    b. Database - The incorporation of a NoSQL database in the system underscores its cost-effectiveness and expeditious storage capabilities,aligning with the current trend of leveraging efficient and affordable storage solutions.
    c. Model Building - Python provides two of the most versatile libraries, namely Tensorflow and Keras, for developing deep learning models. Therefore it proves to be the best language for developing hand gesture recognition and facial recognition module

1.9 Project Outcomes and Deliverables

1. Initially, the user's face is detected by the camera on the lock for face recognition and the user is identified.
2. If the system recognizes the face as the master user, it will then proceed to verify the person through their hand gestures. If the face is recognized as a familiar user, a sound module will announce their presence. However, if the system doesn't recognize the face, an alarm will be triggered.
3. The pattern performed by the master user is detected by the camera and accordingly detects the precise correct unlocking pattern to trigger the lock.
4. Upon accurate hand gesture and pattern recognition, the lock will be triggered and will accordingly be unlocked.

1.10 Novelty of Work

Our aspiration is to develop a locking system that combines robust security measures with user-friendly independence for individuals with visual impairments. While existing market options, such as biometric and optical scan systems, fall short in terms of solo usability for the visually disabled, our innovative solution introduces a distinctive two-way authentication process. Our system stands out by implementing face authentication followed by hand gesture authentication, a unique two-factor approach not present in current systems.

Our focus extends beyond mere convenience; we are committed to crafting a security system tailored specifically for visually impaired users. Striving for minimal error and reduced time delays, we are dedicated to optimizing accuracy in both face and hand gesture recognition algorithms. Significantly, we aim to mitigate the impact of background interference on these algorithms, enhancing overall reliability.

In our pursuit, we aim to carve a niche in the market, offering a groundbreaking device that not only addresses the unique needs of visually impaired individuals but also introduces a new standard in secure and user-friendly locking systems. By prioritizing security, ease of use, and cutting-edge technology, our ultimate goal is to provide visually disabled individuals with a locking system that not only meets their daily needs but also instills a sense of confidence and autonomy in their daily lives.

2. Requirement Analysis

2.1 Literature Survey

2.1.1 Theory Associated With Problem Area

A report by the World Health Organization (WHO) and International Agency for Prevention of Blindness (IAPB) stated that there are approximately 285 million people around the world who are visually impaired. Visually impaired people face limitations to carry out movements and their daily activities without assistance. Moreover, almost 90% of them have to depend on others to ensure their safety. Thus special considerations are required to make the systems utilizable for them. There is no such secure lock that exists for blind people. So this project aims to build a two-factor secure lock that can be used independently by visually disabled people without any assistance. They can check and control who is at the door. This helps them to move freely in the house without any fear that someone can enter without their knowledge or permission.

2.1.2 Existing Systems and Solutions

The literature survey showed that a limited number of studies were conducted focusing on assistive systems for visually impaired users, and even fewer automatic door authentication systems exist for the visually impaired. The existing systems do not address all the needs of the visually impaired but have certain features that we seek to inculcate in our research, like face recognition, voice command control, and gesture control. Some of the existing devices and systems are the Swing Door Lock[1], a flexible door handle that has numbers on a circular Numpad, and with the help of upward or downward movements of the handle, the number combination set by the user can be entered. Another device in place is the YALE ENTR Smart Door Lock[2], which features a keyless lock that can be unlocked using a smartphone or a Bluetooth-enabled device, fingerprint reader, or touchpad reader

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2.1.3 Research Findings for Existing Literature

Table 4: Research findings for existing literature

S. No	Roll No.	Name	Paper Title	Tools/Technology	Findings	Citation
1	102017112	Khushi Goel	Charade: remote control of object using freehand gestures	VPL DataGlove, Computer Vision	A useful method for measuring the bendings of each finger and the position and orientation of the hand in 3D space relative to the active zone, to identify the gesture	[3]
2	102016100	Ayush Goel	Robust Structure from Motion using Motion Parallax	Image Processing	Showed decent results by performing a 3-D visual interpretation of hand gestures, at a man-machine interface, using gloves, affixed with markers	[4]
3	102016041	Asmi Lakhani	Design and Implementation of Automated Door Accessing System with Face Recognition	Computer Vision, GSM module	Facial recognition gives good results and is highly secure as the face is matched with the database, alerting users via SMS.	[5]
4	102016056	Nimit Gupta	Biometric Voice Recognition in Security System	Signal processing	The system successfully recognizes the user's voice, by feature	[6]

					extraction and comparing it with that stored in the database, instructing Arduino to open the door, and rejects all the other impostor's voices.	
5	102196010	Nitish Kumar	Gesture modeling and recognition using finite state machines	Computer vision, classification	Successfully uses finite state machines to identify gestures corresponding to 5 states: start, up, down, left, and right	[7]
6	102017112	Khushi Goel	Understanding Authentication Method Use on Mobile Devices by People with Vision Impairment	Computer Vision,Image Processing	It showed that majority consider fingerprints to be the most secure and most accessible user authentication methods.Survey showed that blind people considered patterns the least accessible methods.	[8]
7	102016041	Asmi Lakhani	Authentication Technologies for the Blind or Visually Impaired.	Computer Vision	Usable Security research aimed at disabled user population becomes extremely challenging is that disabled human subjects are not easily accessible to perform usability studies.	[9]

2.1.4 Problem Identified

Table 5: Problems Identified

Exciting Approaches	Limitations	References
Dynamic gesture identification via continuous video feed	Very little is known about continuous identification, unlike identifying via static images	Robust Structure from Motion using Motion Parallax
Cost structure	The current research is mostly funded by R&D departments of big startups/companies, where the priority is not to cut down prices, making it expensive.	Many open pieces of research
Improved accuracy in face recognition	It is difficult to achieve very high accuracy with most existing algorithms, owing to hardware limitations. High-end cameras will cost more.	Deep Metric Learning for Practical Person Re-Identification
Speed and efficiency	Decreasing false positives, as well as acting as fast as possible. This isn't possible with the equipment being used currently.	Yale ENTR Smart Door Lock

2.1.5 Survey of Tools and Technologies Used

1. OpenCV: Python library of programming functions mainly aimed at real-time computer vision
2. Tensorflow, Keras: Python libraries for deep learning model implementation
3. Raspberry Pi : For local control of sound, latch, and camera, a local

processing module is recommended to provide more efficient and secure control.

4. NoSQL database for storing images of the authorized users.
5. Languages: Python, C++

2.1.6 Summary

The existing locking systems in the market pose significant challenges for independent use by visually impaired individuals and often fall short in terms of ensuring robust security. Recognizing this critical need, our endeavor is to develop a lock specifically tailored to address these limitations. This innovative lock not only provides independent accessibility for visually impaired users but also incorporates a sophisticated two-factor authentication system. The dual authentication mechanism comprises face recognition and hand gestures, bolstering the security features of the lock.

The primary objective of this project is to enhance safety, a paramount concern for visually impaired individuals. By incorporating face recognition technology, the lock ensures that only authorized individuals gain access. The addition of hand gesture authentication adds an extra layer of security, making it a comprehensive two-factor authentication system. This approach not only addresses the safety concerns but also prioritizes convenience for users.

The proposed lock aims to bridge the gap in accessibility and security, empowering visually impaired individuals to confidently and independently control access to their spaces. It represents a significant advancement in ensuring that the safety and convenience of users with visual impairments are prioritized in the design and functionality of security systems.

2.2 Software Requirement Specification

2.2.1 Introduction

A software requirements specification is a description of a software system to be developed. It is modeled after business requirements specification, also known as a stakeholder requirements specification.

2.2.1.1 Purpose

The software requirement specification assures the project management stakeholders and client that the development team has understood the business requirements documentation properly. The information is organized in such a way that the developers will not only understand the boundaries within which they need to work, but also what functionality needs to be developed and in what order. Understanding what order the functionality will be developed in means that the developers have the "big picture" view of the development. This allows them to plan which saves both project time and cost. The SRS forms the basis for a load of other important documents such as the Software Design Specification. It helps in validating with the client that the product which is being delivered, meets what they asked for.

Visually impaired people face limitations to carry out movements and daily activities without assistance. 90% of them have to depend on others to ensure their safety. There is no such secure lock that exists for blind people that they can operate independently. Rest assured, our system will provide our users with complete security without having to rely on someone else. They would not only be protected via a two factor authentication mechanism but will also be able to know who is at the door and then decide accordingly.

2.2.1.2 Intended Audience and Reading Suggestions

The audience is any visually impaired person, who does not want to be dependent on others when it comes to their safety. The system would enable them to take. This document is intended for users and testers. The document represents the detailed idea being implemented through this project. The document shall be read in order.

2.2.1.3 Project Scope

1. Providing a secure locking system for visually impaired people, with a two-factor authentication lock using two modules - face recognition and hand gesture recognition.
2. Preventing any untoward situation by triggering an alarm
3. Providing set, reset, and register facilities to improve user experience

2.2.2 Overall Description

2.2.2.1 Product Perspective

The system will be activated on detecting the human presence in the vicinity. The user would be able to register himself/herself as a master user by capturing face images and subsequently entering a sequence of gestures as the new security key. The system will also allow storing face images of some known faces to the master user, in a database. The user’s face is detected by the camera on the lock for face recognition and the user is identified. If the face is recognized as a master, then the hand gesture pattern is applied for further authentication; otherwise if recognized as a known user, the sound module will announce the person.

The system camera adeptly captures and analyzes the unlocking pattern executed by the master user, ensuring precision in identifying the correct sequence. Through meticulous hand gesture and pattern recognition, the lock seamlessly responds to the authenticated actions of the user. This dynamic integration not only enhances security but also guarantees a smooth and efficient unlocking process. The system's ability to accurately interpret the master user's gestures and patterns underscores its reliability, instilling confidence in users, particularly those with visual impairments, as they unlock the door with precision and ease.

2.2.2.2 Product Features

The system would have the following features:

1. Providing a secure locking system for visually impaired people, with a two-factor authentication lock using 2 modules - face recognition and hand gesture recognition.
2. Preventing any untoward situation by triggering an alarm.
3. Providing set, reset, and register facilities to improve user experience.

2.2.3 External Interface Requirements

2.2.3.1 User Interfaces

A web user portal to register to master users along with their data, i.e the passcode as well as their known users

2.2.3.2 Hardware Interfaces

Hardware interfaces would include a web camera for capturing images of the user as well the gestures, a sound module to announce known users as well as for raising alarms, and finally the lock, which would contain a latch and servo motors.

2.2.3.3 Software Interfaces

For software, we are using Python for image processing and identification modules in our system, besides local memory for computing and storage resources.

2.2.4 Other Non-functional Requirements

2.2.4.1 Performance Requirements

1.
2. Maximum security: There must be virtually no error in authentication, that is minimum false positives so that the user can be guaranteed maximum safety
3. Minimum false alarm: The number of false alerts should be minimal so that the user is not disturbed needlessly.
4. Cost-effective: The solution should not be very expensive and not have high deployment costs, otherwise not everyone will be able to afford it.
5. Scalability: The solution should be scalable to accommodate large numbers of

users.

2.2.4.2 Safety Requirements

Ensuring the security integrity of the lock system, particularly the latch, is imperative to prevent unauthorized entry through forceful attempts. Concealing the latch is paramount, preventing any external manipulation to compromise the system's integrity. Given the potential for system failures, a robust strategy is in place to address this concern. Automatic backups will be systematically conducted at regular intervals, safeguarding the facial and gesture recognition data of users. This precautionary measure not only enhances the reliability of the system but also serves as a protective mechanism against data loss or system disruptions.

The concealed design of the latch serves as a deterrent against tampering, bolstering the overall security architecture. Meanwhile, the periodic automatic backups act as a fail-safe, preserving critical user data even in the event of unexpected system glitches. These dual measures collectively contribute to fortifying the lock system's resilience, ensuring continuous and secure functionality while prioritizing the safety and peace of mind for users.

2.2.4.3 Security Requirements

A user will gain entry only upon successful authentication by the system, otherwise, there will be no effect on the lock.

2.3 Cost Analysis

Fixed Cost

Table 6:Cost Analysis

Item Name	Cost
12V 1 Channel RF Wireless Relay Module	508
Raspi Camera	354
Electric Latch	500
Jumper Wire	240
AC DC power Supply Module	429
IR Proximity Sensor	83
5 V 1 Channel Relay Module	43
Adapter 120 2amp	250
Mini HDMI Cable	349
Buzzers	55
USB to Type Cable	100
Miscellaneous Cost	500
Total	3410

2.4 Risk Analysis

Failure of the image and/or gesture recognition modules will lead to incomplete and invalid authentication, resulting in mishaps. The camera and the lock latch, if damaged, will render our system useless. Hence they must be well enclosed to protect them from external damages. Also, there must be decent illumination for the system to give the best results.

3. Methodology Adopted

3.1 Investigative Technique

The primary objective of our project is to aid the visually disabled person to handle locks without external support. This aim will be achieved by installing a camera in front of the door along with a raspberry pi module connected to it. Raspberry Pi will also include a Wifi module for transmitting data to the cloud for processing/process it locally. The device will be activated as soon as the camera detects a face in front. The user will have to pass 2 levels of authentication to pass namely – face recognition and hand gesture sequence or the master will grant access based on face authentication only.

The project is divided into the following modules:

- Camera Module
- Face Module
- Hand Module
- Sound Module
- Latch Module

Independent variables are those for which value shift does not depend on other factors, and are changed to determine the value of dependent variables. The independent variables of our project are as follows –

- Network connectivity changes from location to location
- Background lighting for the device and can't be controlled at all places

Dependent Variables are those which for estimation depend on other factors i.e. independent variables, and are changed to determine the impact of dependent variables. The dependent variables of our project are as follows –

- Background lighting will determine the performance of the device

Constants are certain variables not changed during the analysis or set during the experiment. The constant variables of our project are as follows-

- The field of view of the camera and proximity sensor where it will be able to detect the face and hands

Table 7: Investigative Technique

S.No	Investigative Projects Techniques	Investigative Techniques Description	Investigative Projects Example
1	Descriptive	Different scientific and exploratory researches were found. After studying different techniques developed by many researchers it was established that there are multiple ways to implement the project and boost accuracy.	Depending on the use case various techniques were found like using pre-trained embeddings of faces, feeding embeddings to further ML algorithms.
2	Comparative	Merging of special features of different techniques would lead to an increase in accuracy and fulfill use case requirements,	Using only CNN to train the recognizers and using pre-trained models for the same purpose gave different results.
3	Experimental	For creating an appropriate model, different architectures can be used and tuned.	The recognition module when made using deep learning model architecture has different transfer learning models to be used to get maximum accuracy.

3.2 Proposed Solution

The purpose of this project is to provide a blind person the ability to operate on a door lock without actually using a key lock. A user wanting to enter the house must provide either both levels of authentication or get an approval of the master user depending on the result of level 1 of authentication. This project enables the blind user to add the following users:-

- Master users who have access to pass both levels of authentication
- Known users who have faces registered to pass level 1 of authentication and upon recognition will be allowed to enter the house depending on the masters' decision
- Unknown users who haven't been registered and can't enter the house unless masters let them

3.3 Work Breakdown Structure

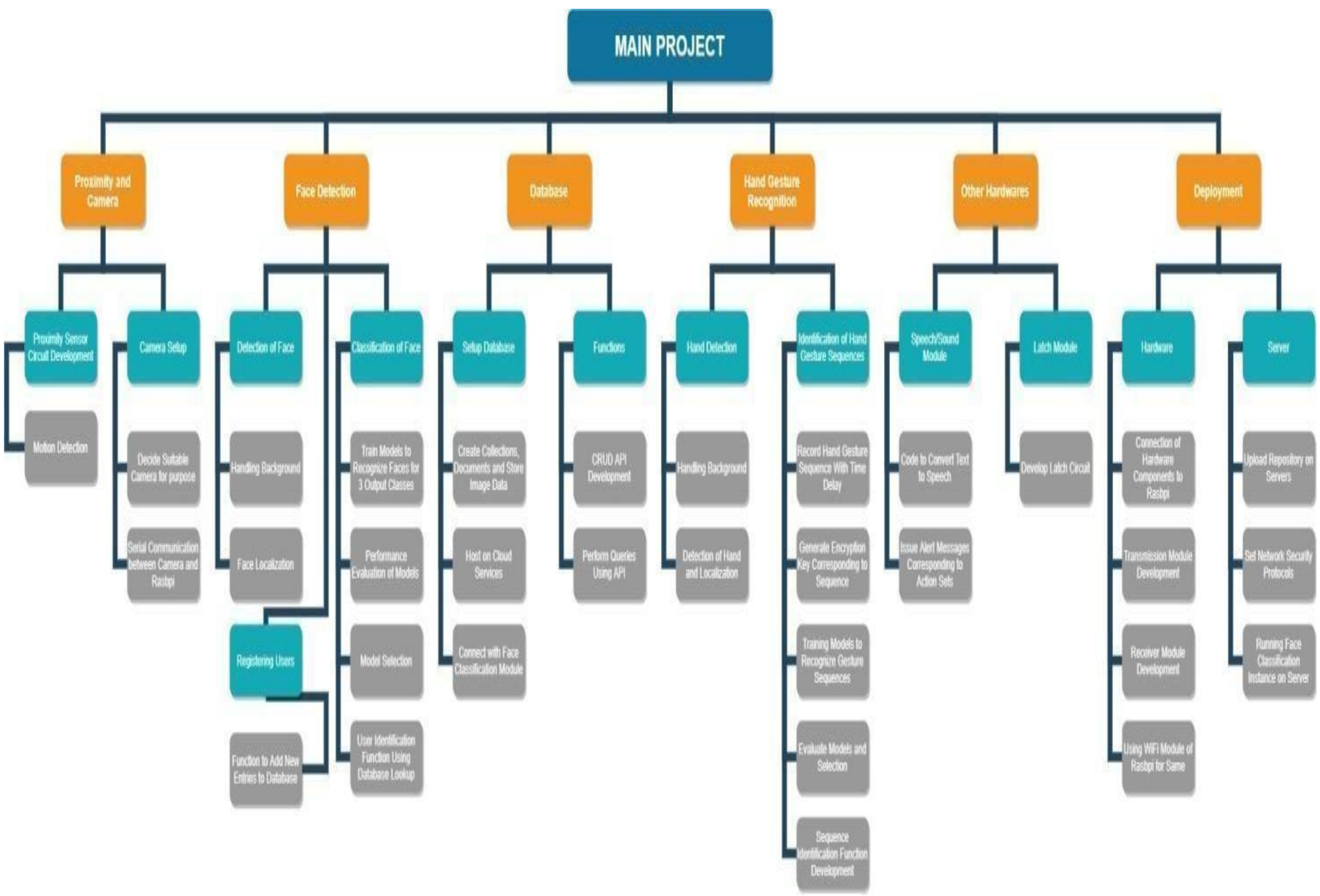

Figure.1 Work Breakdown Structure

The project is divided into the following modules:

- **Camera Module**:Responsible for capturing a live feed in its field of view, this module serves as the visual input for the subsequent components mentioned below.
- **Face Module**:Deploying advanced face detection and recognition models, this component constitutes the first tier of the authentication process. It distinguishes and authenticates users based on facial features, providing a foundational layer of security.
- **Hand Module**:Dedicated to recognizing hand gestures presented in a specific sequence, the Hand Module acts as the second layer of authentication. Users' gestures are analyzed and validated to ensure a comprehensive and multi-tiered approach to system security.
- **Sound Module**:Tailored for auditory output, this module generates distinct sounds corresponding to different user categories. Particularly beneficial for visually impaired users, sound alerts enable informed decision-making based on user-specific audio cues.
- **Latch Module**:Mechanical in nature, the Latch Module responds to electrical signals from the recognition modules. This pivotal component translates authentication outcomes into physical action, securing or releasing access to the designated space.

  .

3.4 Tools Technology

- NoSQL database for storage of images.
- OpenCV – Python library for image processing that provides multiple functions for computer vision tasks.
- Raspberry Pi : For local control of sound, latch, and camera, a local processing module is recommended to provide more efficient and secure control.

4. Design Specifications

4.1 System Architecture

4.1.1 Component Diagram -

A component diagram is a visual representation in UML that illustrates the organization and relationships among modular units (components) in a system. It highlights how components interact, showcasing dependencies, interfaces, and connections, aiding in the design and communication of system architecture.

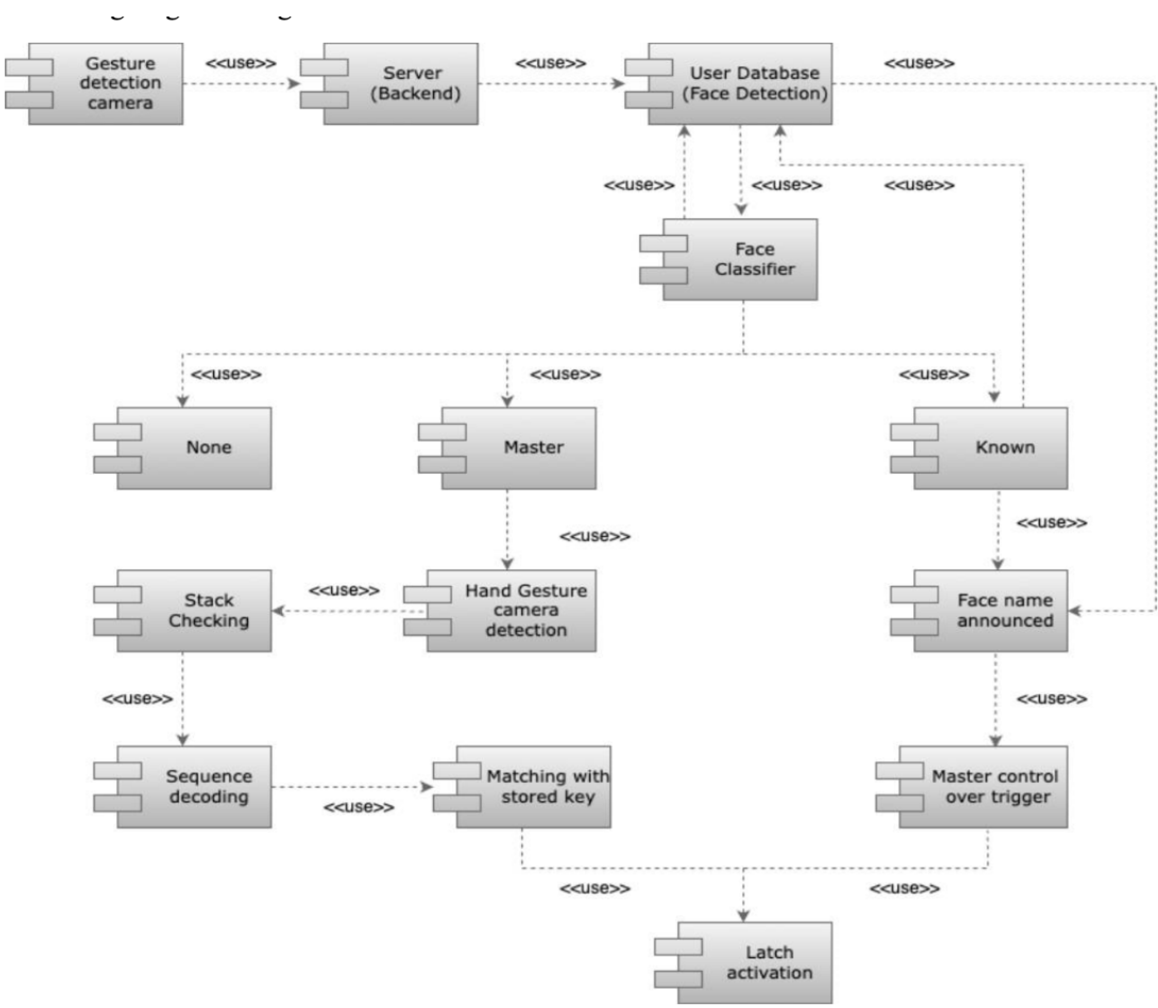

Fig - 2: Component Diagram

4.1.2 Block Diagrams -

The presented block diagram offers a graphical overview of our project's software architecture. It showcases key modules as interconnected blocks, illustrating the flow of data and control between them. As we advance, this diagram will be pivotal for discussions, adjustments, and maintaining a robust software framework.

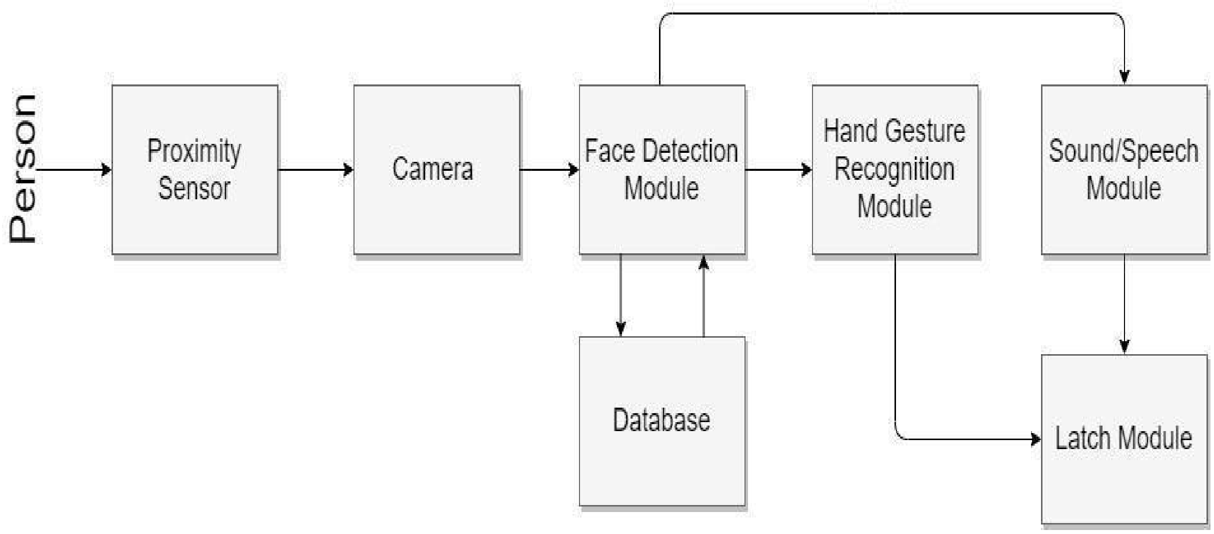

Fig 3: Block diagram

The incorporation of a proximity sensor marks the initiation of the intelligent lock system, detecting the presence of an individual before the lock. Upon detection, the sensor triggers a sound on the buzzer and activates the camera module, initiating a series of advanced recognition processes. A dedicated Face Recognition module is developed to handle the visual data captured by the camera. Deployed on a Raspberry Pi for efficient processing, this module enables the master user to maintain a comprehensive record of known faces within the system's database.

The system's response is dynamic, adapting to different scenarios based on the identity of the person in front of the camera:

- **Master User Identification**:If the detected person is identified as the master user, the system generates a prompt and an activation sound, signaling the initiation of the hand gesture sequence previously saved by the master user.
- **Registered User Recognition**:For individuals with their faces registered in the system, the Face Recognition module identifies the person and provides a speech output, verbally recognizing the individual.
- **Unrecognized User Alarm**:If the person does not fall into either of the recognized categories, the Sound Module triggers a standard alarm, signaling an unrecognized presence.

A Hand Gesture Recognition module is concurrently developed, storing a passkey corresponding to the sequence of gestures demonstrated by the master user. The flexibility for the master user to change the passkey at will adds an additional layer of security to the system.

Upon successful completion of the recognition processes, the Latch Module receives a trigger signal. It responds by opening the latch for a predetermined duration (e.g., 10 seconds), allowing the recognized person to enter the facility. After this period, the latch automatically closes, ensuring security.

For blind users, a collaborative approach is adopted. With the assistance of a technician, a security code is initially entered on the latch. Subsequently, the blind user can register themselves as a master user by capturing face images and defining a unique sequence of gestures as their security key.

Furthermore, the system facilitates the master user in storing face images of known individuals in a cloud-hosted database. Utilizing facial recognition techniques, the device offers an extensive and adaptive security solution, seamlessly integrating advanced technologies to enhance accessibility, convenience, and safety.

4.2 Design Level Diagrams

4.2.1 Activity Diagrams –

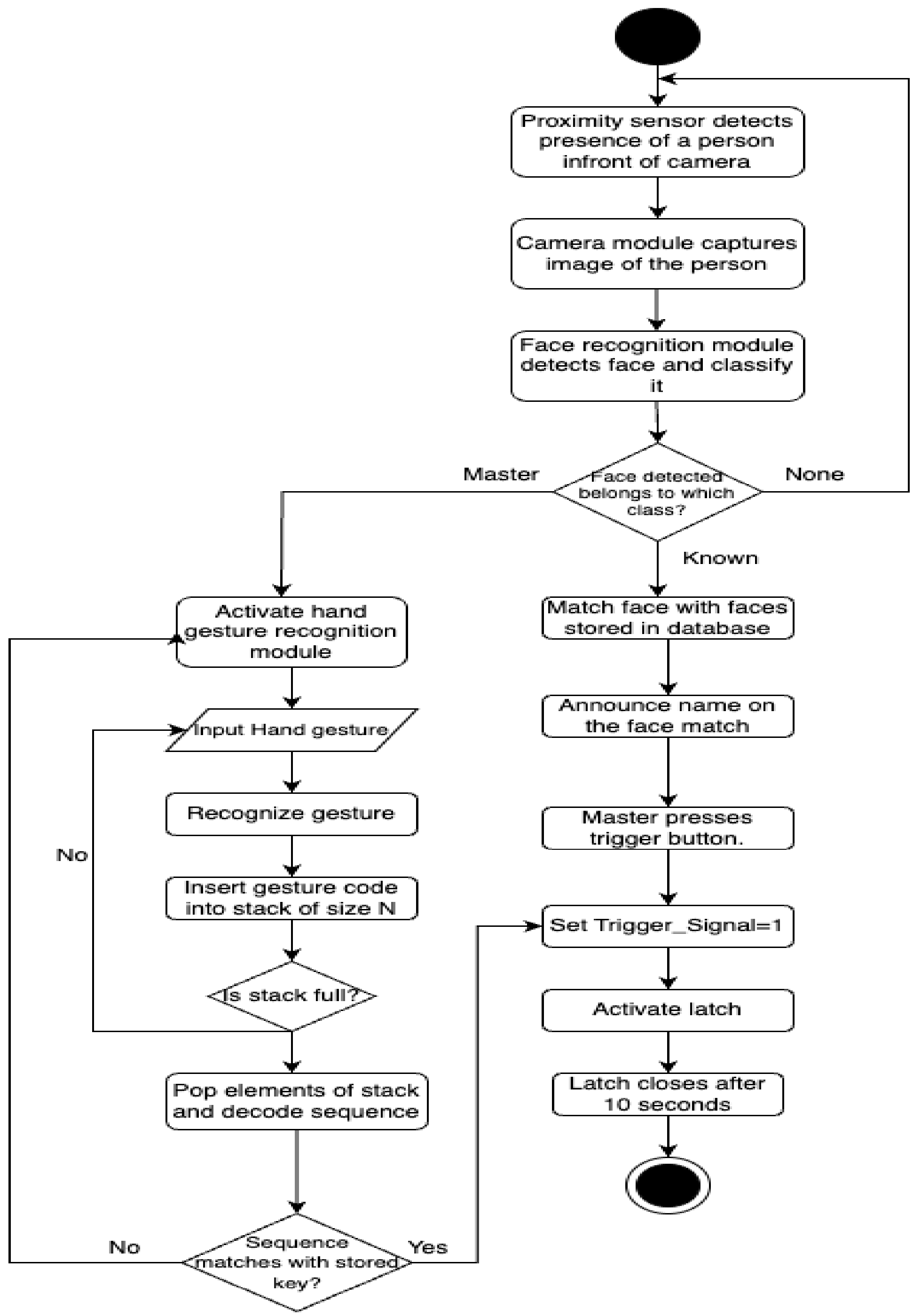

Fig - 4: Activity diagram

- The presented activity diagram delineates the sequential logic and operational flow of the 2-factor Authentication Lock designed specifically for individuals with visual impairments. Upon initiation, the flow advances to a crucial decision point, symbolized by a diamond shape, where the class of the recognized face is determined.
- Should the recognized face be classified as belonging to the master user, the hand gesture module is subsequently activated. This component involves the development of a hand gesture recognition module, designed to securely store a passkey associated with the unique sequence of hand gestures demonstrated by the master user. Importantly, the master user possesses the exclusive privilege to modify this passkey at their discretion, enhancing the system's adaptability and security.
- Conversely, if the recognized face is identified as belonging to a known face in the database but not the master user, the system proceeds to announce the name of the recognized individual. Simultaneously, the master user is prompted to unlock the latch accordingly, demonstrating the system's ability to offer personalized responses based on the recognized user category.
- In cases where the recognized face does not fit into either of the aforementioned categories, the system seamlessly directs to the sound module. This prompts the generation of a conventional alarm, signaling an unrecognized presence and providing an audible alert to the master user.
- This intricate procedural logic ensures that the 2-factor Authentication Lock for the Visually Disabled is not only adaptive to different user categories but also prioritizes security and user-centric functionality. By incorporating advanced facial and hand gesture recognition technologies, the system enhances accessibility and convenience for visually impaired users while maintaining a robust and secure authentication process.

4.2.2 State Diagrams –

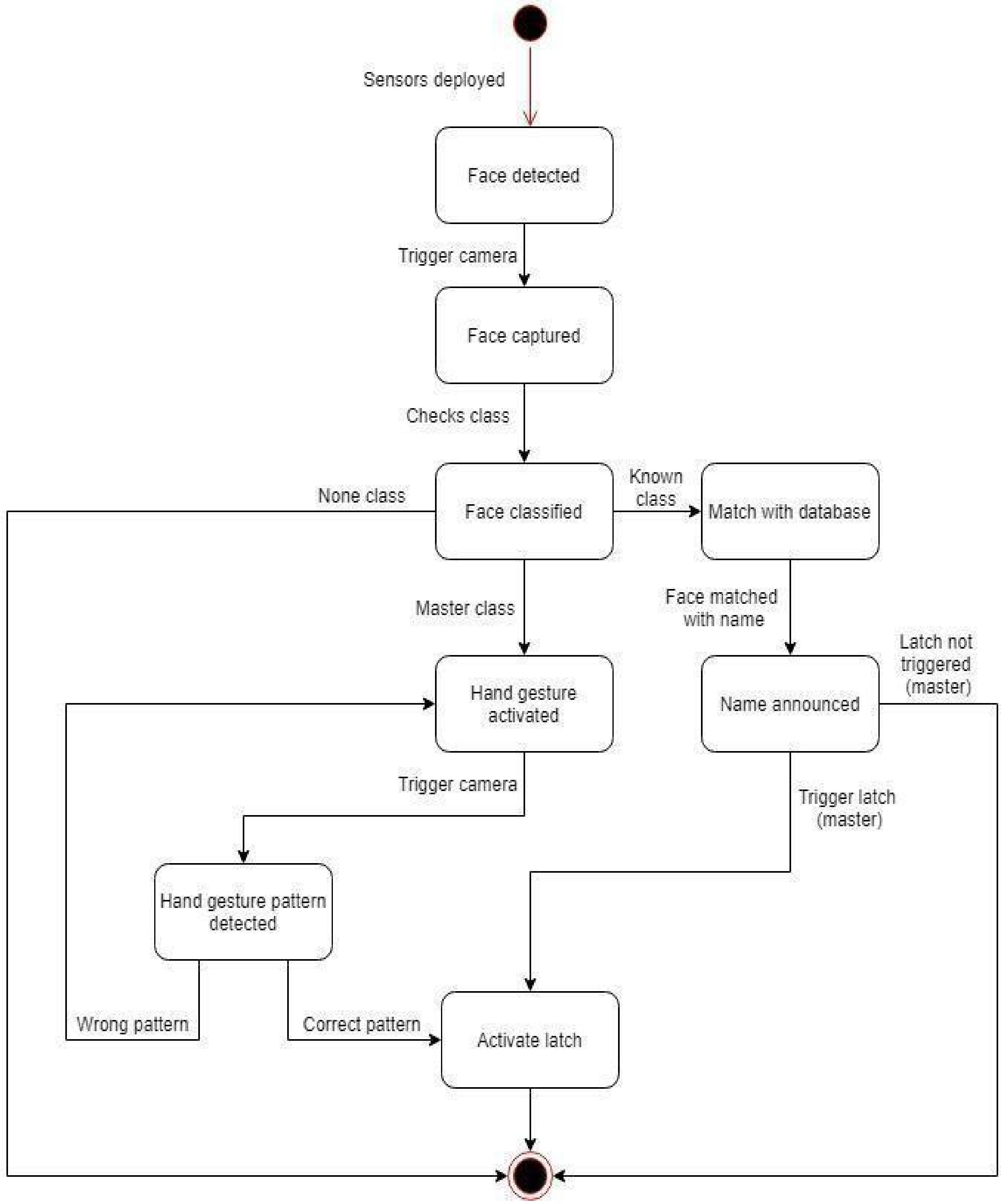

Fig - 5: State diagram

- The above image depicts the different states of the 2-factor authentication lock. Initially, the face is detected and is classified into its categories. From there, it goes into different states depending on the class of the recognized face.
- One state is for the known face where the name is announced for the master to unlock the trigger for.
- The other state is for the master face from where the hand gesture recognition state is triggered.
- Both the states end when the final state is achieved i.e. when the latch is activated after the 2-factor authentication.

4.2.3 Class Diagram -

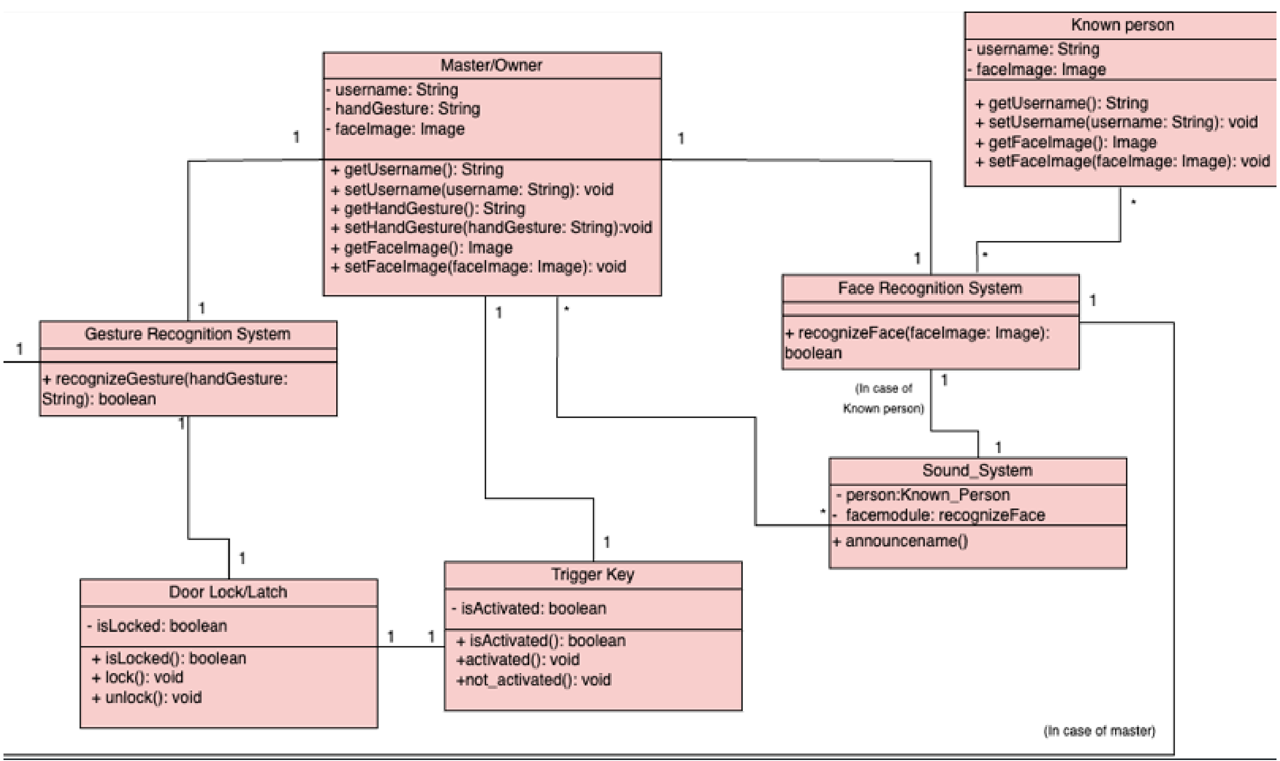

Fig - 6: Class diagram

4.2.4 Data Flow Diagram-

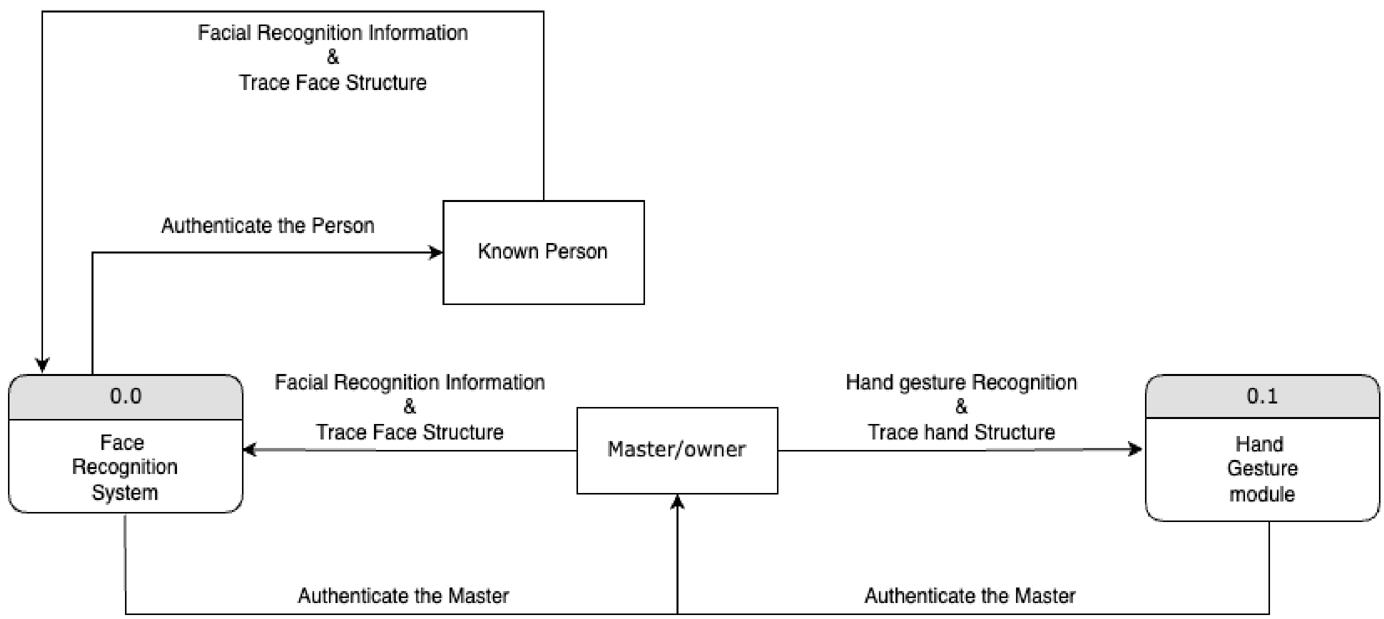

Fig - 7: Level 0 DFD diagram

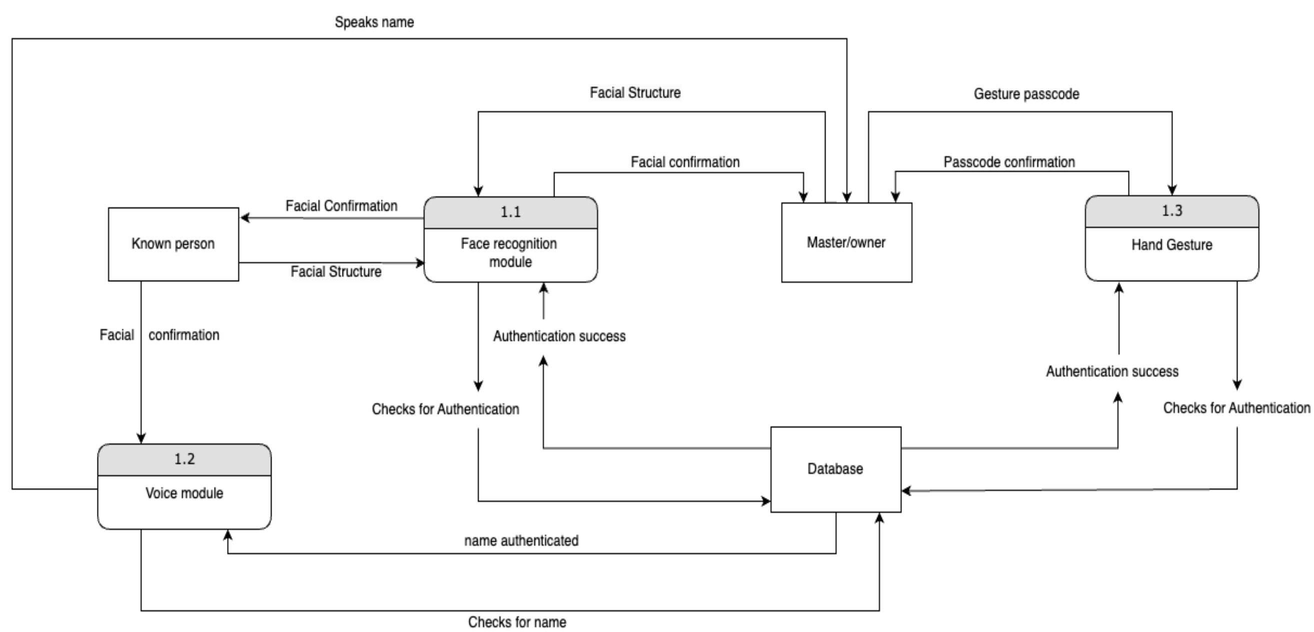

Fig - 8: Level 1 DFD diagram

4.3 User Interface Diagrams

4.3.1 Use Case Diagrams

A use case diagram is a visual representation that illustrates how a system interacts with external entities, known as actors, to achieve specific goals or functionalities. It provides high-level view of the system's functionality and the ways in which external entities interact with it. Use case diagrams are part of the Unified Modeling Language (UML) and are widely used in software engineering and system design.

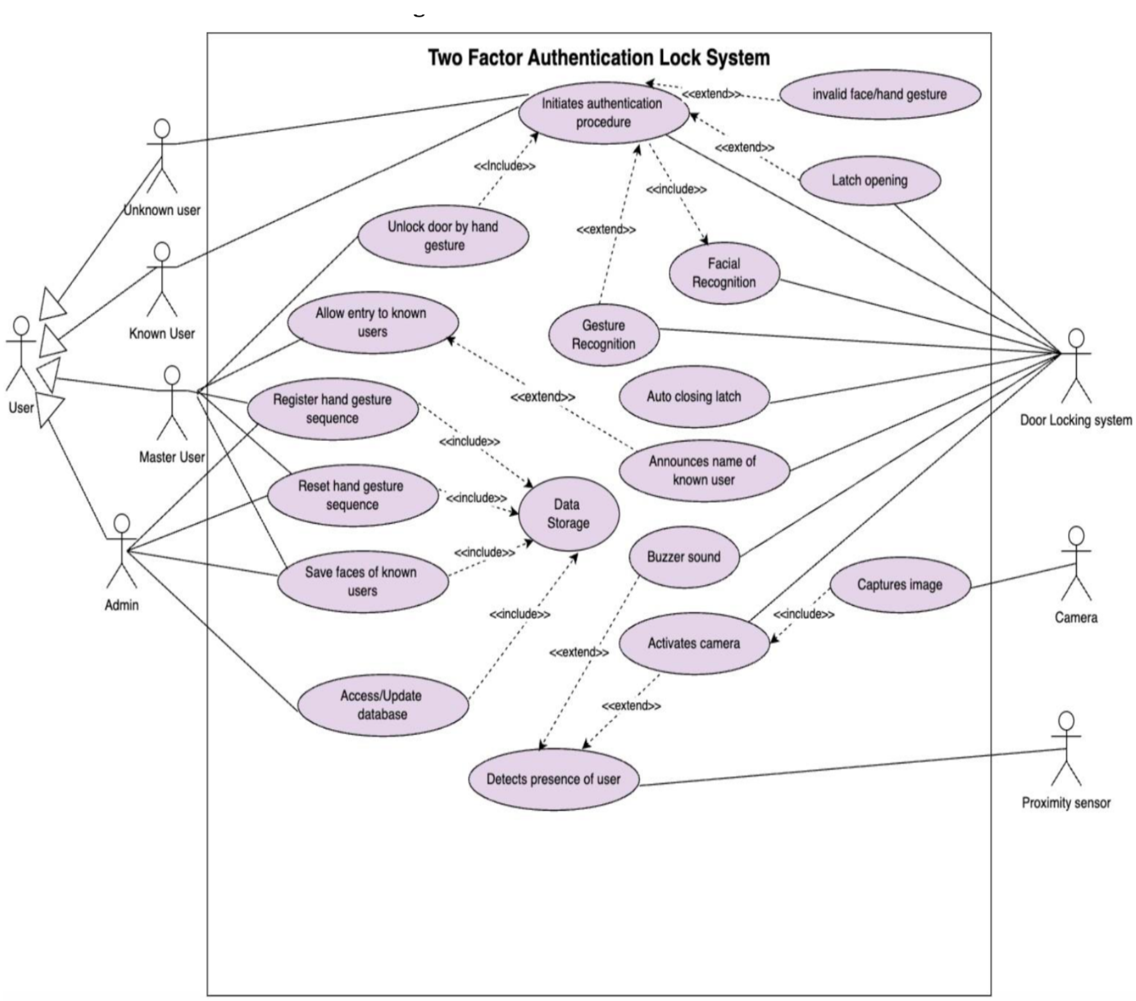

Fig - 9: Use case diagram

4.3.2 Use Case Templates

Table 8:Use Case Template

Use Case Title	User entry through the door
Use Case ID	UC-01
Description	To elaborate how a user will gain entry through the door, which will open automatically subject to completion of the 2-factor authentication procedure.
Primary Actors	User (master/blind user, known user, unknown user)
Secondary actors	System Admin
External h/w	Proximity sensor, camera
Precondition	1. The system has been installed by the technicians 2. The blind user has been registered as the master user and the known users are stored in the database 3. The user is in the vicinity of the door system
Postcondition	1. The system latch goes back to the deactivated state 2. Door remains closed 3. Master user gets the final say for allowing entry of others.
Normal Flow	1. The user is in the range of proximity sensor 2. The proximity sensor detects the presence and the camera module is turned on 3. The camera captures the face of the user 4. The system verifies the image to confirm if this is the master user 5. The master user then inputs the hand gesture sequence 6. The system stores the sequence and verifies it with the stored passcode 7. The system then activates the latch 8. The door is opened and the user can enter
Alternative Flows	In step 4 of the normal flow, if the user identified is not the master user then,

	1. The system matches the image with those in the database 2. If an image is found, then the system classifies the user as a known user and announces his/her name 3. The master user will authorize the entry of this user 4. Use case resumes at step 7 of the normal flow
Exceptions	In step 4 of the normal flow, if the user is neither classified as the master user or a known user, then: 1. The latch will remain deactivated 2. The door will not be opened under any circumstances.

4.3.3 Swimlane Diagram

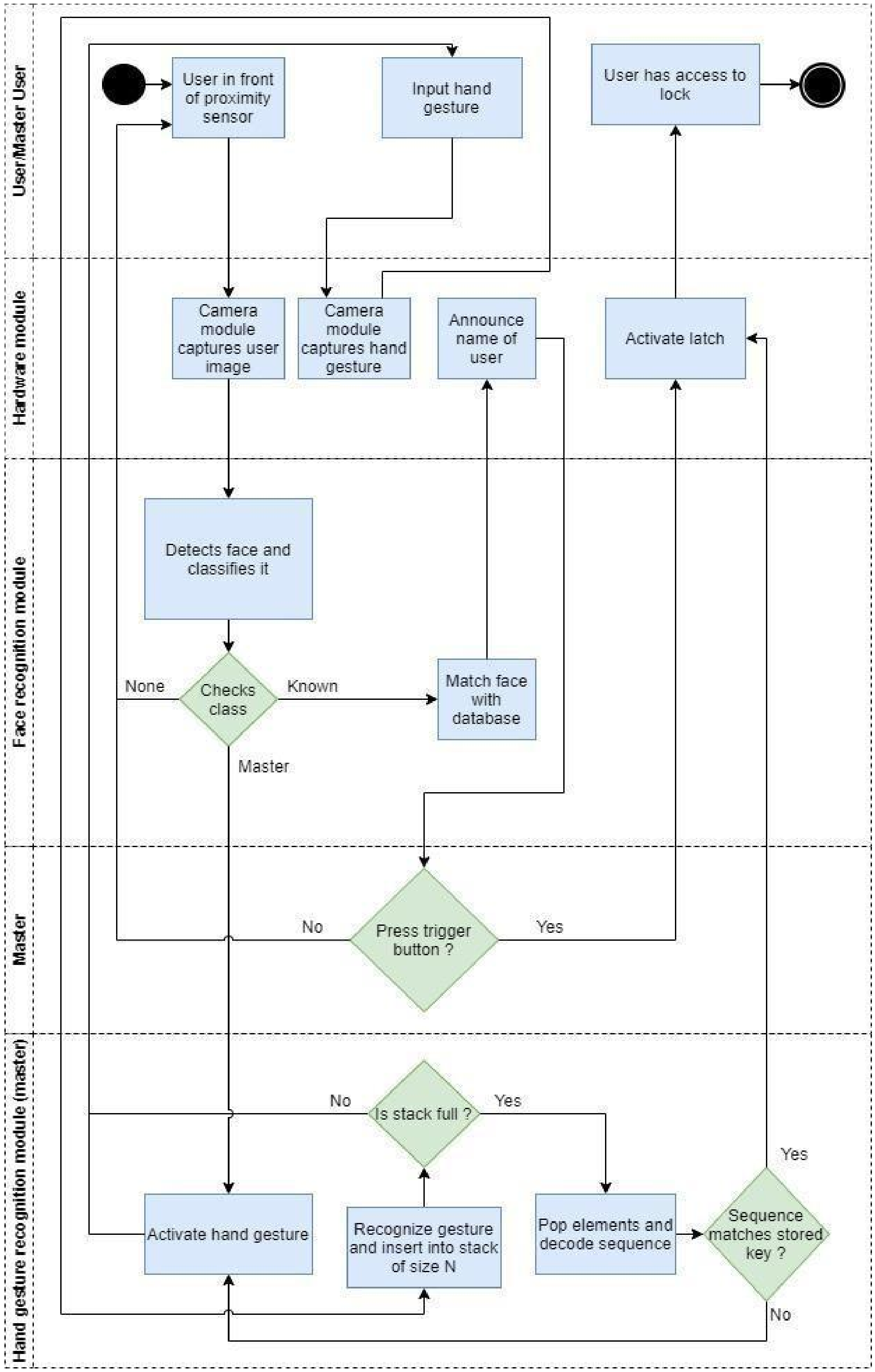

Fig - 10: Swimlane diagram

A swimlane diagram functions as a specialized flowchart that elucidates the roles and responsibilities of various entities within a process. Drawing inspiration from the lanes in a swimming pool, this diagram brings transparency and accountability to a process by allocating specific process steps to distinct horizontal or vertical "swimlanes." Each swimlane represents an individual, workgroup, or department involved in the process, fostering clarity in understanding the workflow.

The swimlane diagram serves as an invaluable visual tool by delineating connections, communication channels, and handoffs between these lanes. By metaphorically aligning process participants within their designated lanes, it enhances comprehension of the sequential steps taken by each entity. This visual representation is not only effective for showcasing the workflow but also serves to pinpoint potential inefficiencies, redundancies, and areas of waste within the process.

In this particular swimlane diagram, the process is compartmentalized into five distinct categories, namely: User/Master User, Hardware Module, Face Recognition Module, Master, and Hand Gesture Recognition Module. Each category or swimlane encapsulates the functionalities and activities specific to that entity. The visual depiction offers a comprehensive overview of how these entities interact, communicate, and collaborate in the overall process.

By leveraging the swimlane metaphor, this diagram not only enhances the understanding of the process but also aids in identifying opportunities for streamlining, optimizing, and improving the efficiency of the workflow. Overall, the swimlane diagram proves to be a powerful and intuitive tool for visualizing complex processes, facilitating effective communication, and driving process improvement initiatives.

5. Implementation and Experimental Result

5.1 Experimental Setup -

The project has been simulated on a laptop with 8GB internal RAM. The project is running on Command Line and Raspberry Pi OS. It uses the in-built camera of laptop to capture face of the user and detect hand gestures and speakers of the laptop to give instructions to the user. The steps for the simulation of the project are as follows:

1. The project is run on Command Line and Raspberry Pi OS.
2. The camera captures the face and gesture of the user to perform recognition.
3. The speaker gives relevant instructions to the user
4. After processing access will be granted or denied accordingly and if granted latch will be opened after signal is given to raspberry pi.

5.2 Experimental Analysis

5.2.1 Data

For the initial phase of the testing, we focused on the module which needed face data, we collected pictures of people to create our own dataset The labels are as follows:-

- Master
- Known
- Unknown

.

For hand gesture detection we monitor the position of landmarks of the fingers to detect the number shown by the user. In order to do this, we have collected several images of hands displaying different numbers from 0 to 5, to enable the model to detect the hand and the fingers.

5.2.2 Performance Parameters

We are experimenting our model on different test cases. The first one is detection of face in different lighting conditions and apart from face other objects in the background should not be detected. Second is face recognition ,which should have very high accuracy.The model is selected dynamically by comparing all the models and model which gives best result is chosen.The model chosen according to current dataset is logistic regression with accuracy 98% and then is further tuned using random grid search. After that next test case include detection of hand landmarks for gesture recognition and it should be done dynamically. Then the final module where we focus on sending the signal to the raspberry pi module as quickly as possible so that latch can be opened without much delay. The main parameters are time and accuracy for our project.

5.3 Working of the project

5.3.1 Procedural Workflow

Our project consists of three major workflows. The first one i.e. the face recognition module is responsible for detecting the face of the user by extracting the face embeddings. This gives us the name and category to which the user belongs. This information is used to call the gesture detection module accordingly. The second flow is the detection of gestures of the user classified as the 'master'. The master will then show the correct gesture sequence which is matched with the passcode set initially. In case the user is a known user, his/her name is announced on the speaker. The final workflow consists of the latch module, where on showing the correct gesture sequence, the signal is sent to unlock the latch and let the user in.

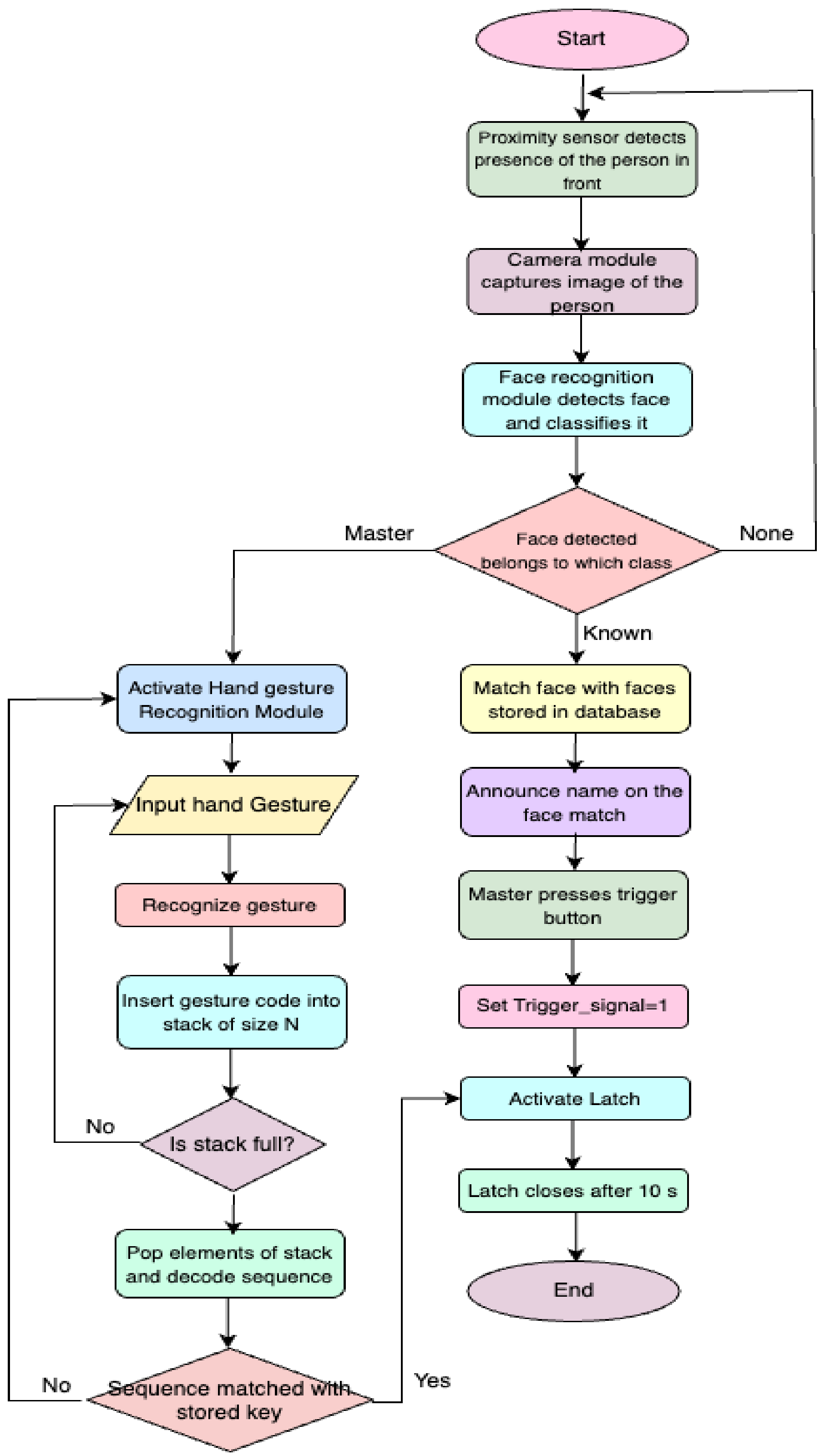

Fig - 11: Procedural Workflow

5.3.2 Algorithmic Approaches Used

1. **Detecting user at the door**

```
def start() -> str:
    username = recognize_face()
    with open("users_register.json", "r") as file:
        data = json.load(file)
    if data.get(username) is None:
        speak_text('Access Declined')
        return 'Access Declined'
    if data[username]["category"] == "Normal":
        speak_text("Detected " + username)
        return 'Access Declined'

    pin = get_pin(4)
    user_pin = data.get(username)["pin"]
    print(user_pin)
    if pin == str(user_pin):
        speak_text('Access Granted')
        return 'Access Granted'

    speak_text('Access Declined')
    return 'Access Declined'
```

Algorithm 1: Algorithm for user detection

This Python script establishes a client-server interaction for a Raspberry Pi-based security system. Upon receiving a "Detect" command from the client, the server recognizes a user's face, checks their pin against registered data, and communicates the access status back to the client. The script enables continuous interactions between the server and client, involving face recognition, pin verification, and access status communication.

2. Logic for face recognition

```
faces_in_current_frame = face_recognition.face_locations(img_small)
    encode_current_frame = face_recognition.face_encodings(img_small,
faces_in_current_frame)

    for encoded_face, face_loc in zip(encode_current_frame, faces_in_current_frame):
      matches = face_recognition.compare_faces(encoded_list[0], encoded_face)
      face_distance = face_recognition.face_distance(encoded_list[0], encoded_face)
      true_indexes = [i for i, value in enumerate(matches) if value]
      if len(true_indexes) == 0:
        continue

      min_value = np.min(face_distance[true_indexes])
      min_index = np.argmin(face_distance[true_indexes])
      if min_value < 0.5:
        print(encoded_list[1][true_indexes[min_index]])
        detected_names.append(encoded_list[1][true_indexes[min_index]])
    if len(detected_names) == samples:
      counts = Counter(detected_names)
      return counts.most_common(1)[0][0]
```

Algorithm 2: Algorithm for face recognition

This Python script utilizes face recognition to identify individuals through a webcam. It loads pre-encoded face data, captures video frames, and compares them against the stored data to recognize known faces. The script continuously runs until it either detects a specified number of samples or reaches a timeout. The detected names are then counted, and the most frequently occurring name is returned as the recognized person. The script showcases a simple yet effective implementation of face recognition using the face_recognition library and OpenCV.

5.3.3 Project Deployment

All the components/ modules included in the architecture of our project are represented in the following diagram along with their relations

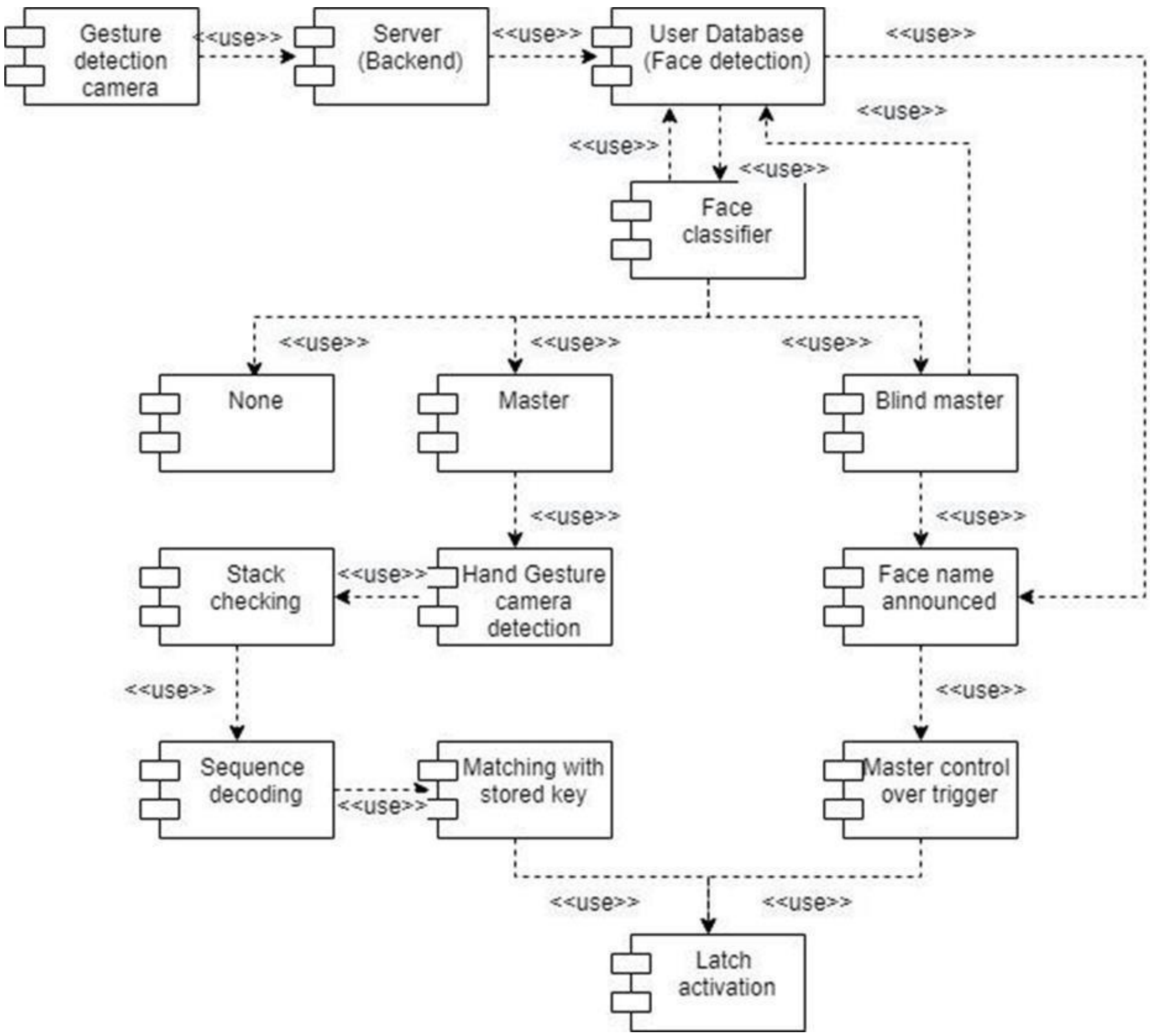

Fig - 12: Deployment Diagram

5.3.4 System Screenshots

1. Face Recognition module

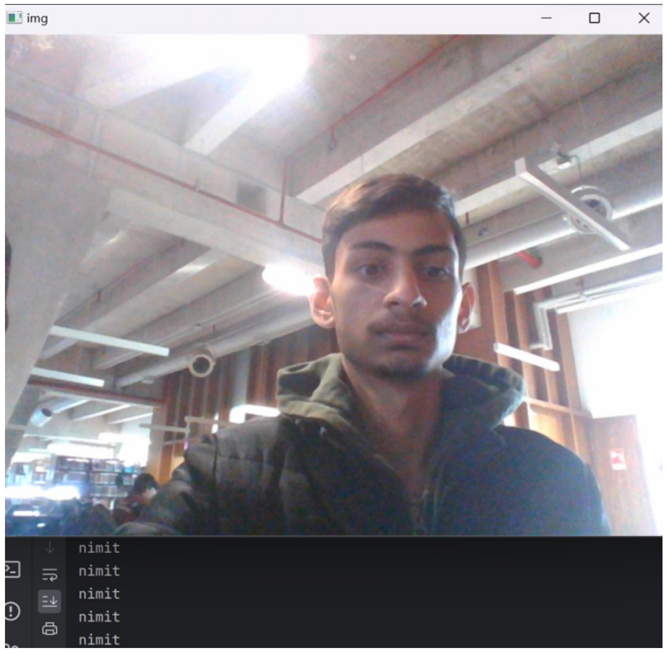

Fig - 13: Face recognition

2. Hand Recognition module

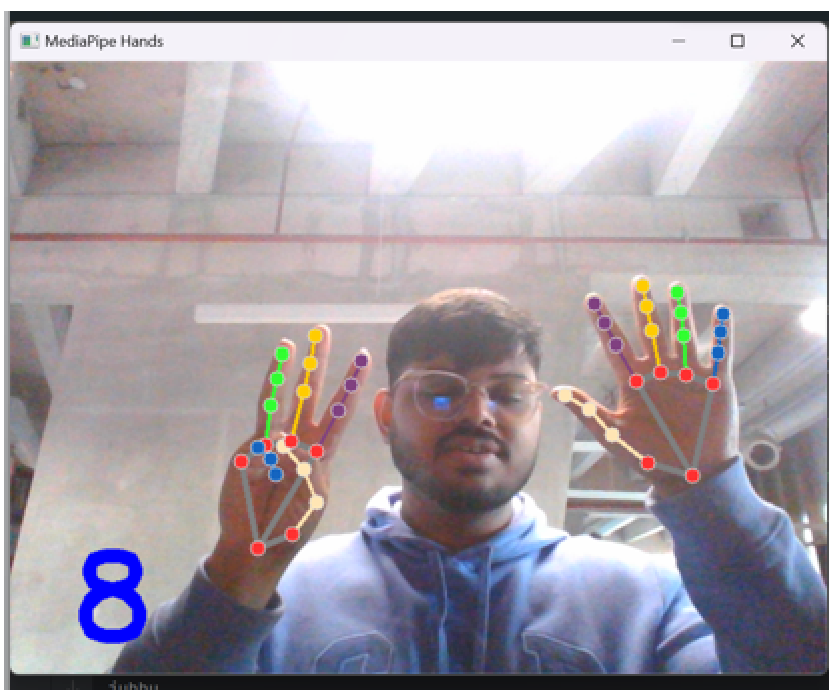

Fig – 14: Hand recognition

3. Passcode entry and matching

```
C:\Users\hp\anaconda3\envs\face-detection\python.exe D:\test\face-detection\client.py
CLIENT: connected
jubbu
jubbu
jubbu
jubbu
jubbu
INFO: Created TensorFlow Lite XNNPACK delegate for CPU.
1
2
3
4
1234
CLIENT: disconnected
CLIENT: connected

Process finished with exit code -805306369 (0xCFFFFFFF)
```

Fig - 15: Passcode Entry and matching

4. Hardware Component

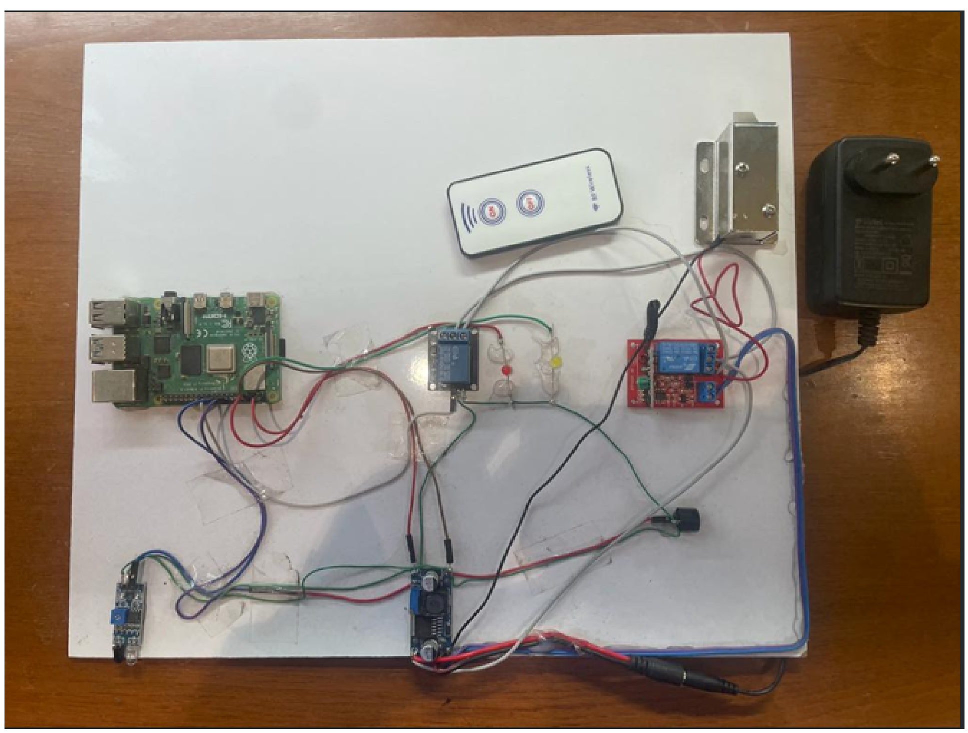

Fig - 16: Hardware Component

5.4 Testing Process

5.4.1 Test Plan

The application developed has been extensively tested. The various testing techniques and methods and their results have been documented in subsequent sections. All the modules were tested separately and cohesively.

5.4.2. Features to be tested

The tested modules include:

- Face Module (Detection, Recognition, and Categorization)
- Hand Module
- Raspberry Pi Module (Hardware)
- User Application

In addition to these main modules numerous other parts of the application like cloud processing and storage were also tested.

5.4.3 Test Strategy

The strategy for the test is fairly straightforward and simple. We test all the parts individually as well as collectively. This can be done using different types of testing techniques like Black Box testing (for testing each component separately) , Integration Testing (for testing the integrated module to verify combined functionality) . We have also used Unit testing to test individual parts.

5.4.4 Testing Techniques

Unit Testing:

Module 1: Face Module

Input: Input from web camera

Output: Name and category of user

Module 2: Hand Module

Input: Input from web camera

Output: Passcode sequence and password match signal encoded (On console and speaker)

Module 3: Raspberry Pi Module

Input: Encoded message

Output: Latch open/close

Integration Testing:

Module 1: Main function

Input: Input from Web Camera

Output: Encoded message

Module 2: User Application

Input: Input from Web Camera/Command

Output: Face Embeddings, User Register added/deleted/updated

Black Box Testing:

Table 9:Black Box Testing

Input	Expected Output	Actual Output	Successful/Unsuccessful
User detected as master and correct hand gesture is given	Latch is opened and access granted	Latch was opened successfully and access was granted	Successful
User detected as master and incorrect hand gesture is given	Access denied	Access was denied and latch not opened	Successful

User detected as known	Announcement of name of the person through speakers	The name of the person was announced through speakers	Successful

5.4.5 Test Cases and Test Results:

Table 10:Test Cases and Test Results

S.No.	**Test case**	**Input**	**Expected Output**	**Actual Output**	**Result**
T001	Face Detection	Facial input from camera	Successful detection	Face detected and recognition started	Successful
T002	Face recognition	Face embeddings extracted from the facial input	User recognised	Recognition displayed as percentage, user name and category detected	Successful
T003	Hand gestures identification	Position of fingers detected from camera input	Successful recognition of number	Number shown by the user's fingers is identified and stored in a list	Successful
T004	Opening of latch with raspberry pi	Signal from client program	Successfully opens the latch	Latch retracted	Successful

5.5 Results and Discussions

- The project has successfully achieved its primary objectives, demonstrating a fully functional system where all components operate seamlessly. The face recognition model efficiently detects and recognizes faces in real-time, and the hand gestures are accurately matched with the passcode, showcasing optimized and effective code implementation.

- The face detection model employed in the project utilizes the Haar cascade frontal face alt algorithm, ensuring reliable and prompt identification of facial features. Complementing this, the CaffeModel from OpenCV DNN is utilized to extract and convert facial features into embeddings, capturing a comprehensive representation of the face.
- For hand gesture recognition, the implementation taps into the MediaPipe library, a robust tool that integrates a sophisticated palm detection model and a precise hand landmark model. This combination empowers the system to achieve accurate and real-time detection of hands, laying a sturdy foundation for recognizing and interpreting diverse hand gestures within the project's overarching framework.
- The successful integration of these components underscores the project's efficiency, offering a reliable and user-friendly two-factor authentication system for individuals with visual impairments. Utilizing advanced models and libraries reflects a commitment to leveraging cutting-edge technologies, ensuring the system's accuracy, adaptability, and effectiveness.

5.6 Inferences Drawn

Following the execution of the start file across various individuals and real-time applications, notable observations and considerations have emerged.:

- The sensor data acquired during these tests revealed the continuous and time-variable nature of the data, emphasizing the need for robustness in gesture recognition. Even minor alterations in hand gestures, especially during activities like handwashing, can result in the system recognizing entirely different gestures. This highlights the importance of refining the gesture recognition algorithms to accommodate subtle variations and ensure accurate performance across various scenarios.
- The implementation of OpenCV has proven to be a pivotal component, showcasing its impressive and formidable face detection and recognition capabilities. The library's extensibility allows for further training using additional

Machine Learning models, a feature harnessed in the project. This adaptability positions OpenCV as a versatile tool capable of evolving with the integration of advanced technologies, aligning with the project's commitment to innovation.

- The incorporation of Google's Mediapipe library has proven to be highly beneficial. Renowned for its versatility, this library excels in real-time detecting hands, palms, and fingers, providing accurate counts during streaming applications. Leveraging this library underscores the commitment to precision, especially when hand gestures are integral, such as in the proposed two-factor lock system.
- Recognizing the importance of user interaction, the suggestion to provide a user application for CRUD (Create, Read, Update, Delete) operations emerges as a strategic move. This user-friendly application ensures seamless interaction with the system, empowering users to manage and customize their experience effectively.
- The testing phase has shed light on the intricacies of sensor data, the power of OpenCV and Mediapipe libraries, and the significance of user-centric applications. These insights pave the way for further refinement, ensuring the system's adaptability, accuracy, and user-friendliness in diverse real-world applications.

5.7 Validation of Objectives

The validation of the proposed objectives is described in the table below.

Table 11: Validation of Objectives

S.No.	Objectives	Status
1	To study about the problems and the needs associated with visually impaired people.	Successful

2	To develop a two-factor authentication lock using two modules - face recognition and hand gesture recognition which will independently run on Raspberry Pi.	Successful
3	To use deep learning models to recognize gestures posed by a blind person and convert them sequentially into a unique passkey.	Successful
3	To create a safe and robust system for blind people that can be used by them independently without any assistance.	Successful

6. Conclusions and Future Directions

6.1 Conclusions

This project started with a vague idea of people coming together to provide a foolproof security solution for visually impaired people. The idea was to implement a lock with 2 levels of security i.e. face recognition and hand gesture verification. The face detection module was successfully used to classify the different users, while gesture recognition enabled the blind user to set a secure passcode used to unlock the door. Therefore, we have managed to harness the power of machine learning and deep learning for providing maximum security.

The Capstone project has been a learning curve for all the members of the group with everyone learning from each other thereby taking our knowledge to a better level. It has been instrumental in increasing our knowledge of software development and tells us about the various processes and documentation associated with it. It has given us greater insights on our course subjects which have been used here thereby giving us the practical implementation of the same. Further, it has helped us develop leadership skills and also has taught us how to work as a team and produce the best outcome.

6.2 Economic and Social Benefits

- Our device will help in decreasing the crime rate against visually disabled people.
- It will help in ensuring the safety of these people as they can operate the lock independently.
- We are trying to create a whole new market that never existed before benefiting both the economy as well as saving lives.
- Our model is dynamic i.e it can and will evolve and improve over time making it more helpful in upcoming times.

6.3 Reflections

The developmental odyssey of crafting a 2-factor lock tailored for the visually impaired has been a dynamic journey marked by an array of challenges and triumphs. The team's highs were palpable when the project seamlessly unfolded according to the outlined plan, contrasted vividly by moments of unease and urgency when unanticipated challenges threw themselves into the mix. This fluid and ever-evolving process emerged as a crucible of experiential learning, where each victory and setback etched valuable lessons into the team's collective knowledge base.

The amalgamation of jubilant successes and formidable setbacks spurred the team to adapt and recalibrate their approach, refining their problem-solving acumen and bolstering resilience in the face of unforeseen obstacles. Beyond the tangible output of a sophisticated 2-factor lock, the project's trajectory became a catalyst for profound personal and professional growth among team members. The journey, laden with its undulating terrain, underscored the iterative nature inherent in engineering projects and, most notably, emphasized the intrinsic value of unwavering perseverance and adaptability when confronted with the multifaceted challenges of innovation and technology.

6.4 Future Work

- The inherent flexibility of Hand Gesture Recognition to synchronize with varying time delays in entering the gesture sequence represents a pivotal aspect of the system's adaptability. This feature not only accommodates users with diverse needs but also caters to individuals with varying response times, ensuring a user-friendly experience for a broad spectrum of users. By embracing this dynamic quality, the lock system attains a level of inclusivity that enhances its accessibility, making it particularly accommodating for individuals with unique requirements or differing response speeds.
- Introducing better cameras into the system marks a significant stride toward elevating the precision of background reduction within detection modules. The utilization of advanced imaging technology equips the device with heightened discernment capabilities, enabling it to operate seamlessly across a diverse range of lighting conditions. This strategic enhancement directly addresses a common challenge encountered in facial and hand recognition systems, where fluctuations in lighting conditions can impede accuracy. The integration of superior cameras empowers the lock system to overcome such challenges, ensuring reliable performance under various environmental settings.
- A key focus on increasing the accuracy of both hand and gesture recognition models represents a fundamental objective. This precision-centric approach is pivotal for refining the efficacy of the entire lock system. Enhancing accuracy not only fortifies the security features of the system but also contributes to its overall reliability and usability. This commitment to accuracy aligns with the paramount goal of delivering a secure, efficient, and user-centric locking solution, meeting the diverse needs of users with visual impairments and reinforcing their confidence in the technology.

7 Project metrics

7.1 Challenges Faced

The journey of our capstone project was marked by numerous challenges that shaped our problem-solving approach:

- In the initial phase of our project, our team embarked on a comprehensive exploration of potential solutions, navigating through a diverse landscape to identify strategies crucial for the development of our unique model. This involved a thorough examination of various methodologies and technologies available in the realm of facial and hand recognition systems. By delving deep into an extensive array of research papers, we gained valuable insights into the approaches adopted by other researchers and engineers when faced with analogous challenges. This thorough exploration not only broadened our understanding of existing methodologies but also inspired innovative adaptations tailored to the specific needs of our 2-factor lock for visually impaired individuals. It served as the cornerstone for laying a robust foundation for our project, emphasizing a research-driven and informed approach to problem-solving.
- The scarcity of data in our specific field posed a significant hurdle, making monitoring a challenging task. With limited benchmarks to compare against, we devised our own system, overcoming the initial shortage of comparative data. However, facial and gesture recognition proved intricate, requiring optimal background, contrast, and lighting conditions. Variations in these factors disrupted experimental results, particularly in discerning the finger landmarks' positions.
- Synchronizing hand movement with recognition emerged as a particularly arduous task. Achieving real-time recognition of gestures demanded persistent efforts, refining the model over time. The intricacies of gesture recognition underscored the importance of favorable conditions and reliable data.
- Moreover, the quest for suitable hardware proved to be a meticulous and crucial endeavor. Balancing performance and cost, we engaged in careful trade-offs,

ensuring hardware choices aligned with project requirements. Navigating through these challenges not only honed our problem-solving skills but also instilled resilience, emphasizing the iterative and adaptive nature of our approach. Ultimately, the project's success stemmed from overcoming these obstacles, leading to valuable insights, innovation, and a deeper understanding of the complexities within the realm of our capstone objectives.

7.2 Relevant subjects

The following course subject’s knowledge will be used in the development of the proposed system:

Table 12:Relevant subjects

Subject code	**Subject name**	**Description**
UCS507	**Software Engineering**	The methodology of agile will be used throughout the process of making the software for this project. As taught in this subject, all the well-suited diagrams and other different kinds of methods will be implemented like SDLC, scrum, UML diagrams, etc. Different kinds of testing strategies will be implemented which we learned in the practical implementation throughout this course.

UES034	**Measurement Science and Techniques**	By virtue of this subject, different sensors will be implanted in the device, which was taught during this course. Use of Raspberry Pi with different sensors will be implemented which we used to conduct different kinds of experiments in the labs. The concept of measuring different kinds of quantities and the concept of IoT will be used during the development of the device.
UML501 and UCS521	**Machine Learning and AI**	By virtue of these two concepts, different ML models will be used to perform hand gesture and face recognition as it is a subfield of AI which aims to teach computers the ability to do tasks with data, without explicit programming. The concept of training ML models to perform computational tasks is used here during the development of the device. All the conceptual and practical knowledge regarding the ML and AL gathered during this course will be implemented in this project.

UCS310	**Database Management Systems**	All the logical and physical database designs will be implemented as taught during this subject. Analysis of database design using E-R data model will be used as implemented during the project for this course. All the conceptual and practical knowledge regarding the database management gathered during this course will be implemented in this project.

7.3 Interdisciplinary Knowledge Sharing

The development of a locking system requires knowledge from multiple domains. It required knowledge of machine learning models, deep learning, and computer vision for developing the software part. For the development of the hardware part, knowledge of raspberry pi and the camera was required.. Also coordinating with teammates specializing in different domains was a challenge. Complete understanding and sharing of knowledge was necessary. Working together to achieve a common goal taught us a lot on how dividing the work is way too important. Overall it was a great experience and we learned a lot from each other.

7.4 Peer Assessment Matrix

In the following peer assessment matrix, points were awarded out of 5(5 being the max).The legend followed is 5-Excellent, 4- Very Good, 3-Good 2-Satisfactory, 1- Unsatisfactory

Table 13: Peer Assessment Matrix

		Evaluation of				
		Khushi Goel	**Ayush Nagpure**	**Asmi Lakhani**	**Nitish Kumar**	**Nimit Gupta**
Evaluation By	**Khushi Goel**	5	5	5	5	5
	Ayush Nagpure	5	5	5	5	5
	Asmi Lakhani	5	5	5	5	5
	Nitish Kumar	5	5	5	5	5
	Nimit Gupta	5	5	5	5	5

7.5 Role-playing and work schedule

The plan of attack towards this problem would be to break it down into smaller problems then pipeline them to form the bigger picture. Our problem could be divided into multiple major parts, being related to machine learning and the others containing the development and hardware parts.

In the same manner, we have decided to divide our team taking into consideration their particular electives.

Table 14:Role playing

S.No	Task	Individuals involved
1.	Reading about the problem statement and the need analysis from various sources available online	Asmi Lakhani, Khushi Goel
2.	Creating the User-Interface Diagrams	Ayush Nagpure, Khushi Goel

3.	Purchasing hardware and cost analysis	Nimit Gupta, Ayush Nagpure
4.	Creating the design level diagram	Asmi Lakhani, Nitish Kumar
5.	Understanding the system architecture	Asmi Lakhani, Nimit Gupta
6.	Face Detection Module	Ayush Nagpure
7.	Hand Gesture Module	Nimit Gupta, Nitish Kumar
8.	Documentation	Khushi Goel, Nitish Kumar

The following work plan was followed to complete the project.

Table 15:Work Schedule

Sr. No.	Activity	Month	Mar Apr		May-Jun				Jul-Aug				Sep-Oct				Nov-Dec			
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Project planning and study of hardware, software requirements	Plan																		
		Actual																		
2	Face recognition module development	Plan																		
		Actual																		
3	Gesture module development	Plan																		
		Actual																		
4	Design Optimisation and Modifications	Plan																		
		Actual																		
5	Circuit designing, Raspberry Pi code	Plan																		
		Actual																		
6	Testing and Modification	Plan																		
		Actual																		
7	Final Report	Plan																		
		Actual																		

7.6 Students Outcome

Table 16:Student Outcome

SO	Description	Outcome
1.1	Applying mathematical concepts to obtain analytical and numerical solutions.	Finding out the embeddings in face recognition, finding out landmarks in hand for recognition of hand gestures, and calculating error and accuracy of model performance.
2.1	Use appropriate methods, tools, and techniques for data collection.	Collected face data from various users which helped us increase our model accuracy a lot.
3.1	Applying engineering techniques for solving computing problems.	The application of techniques that are going to solve the purpose of doing computations for the dataset.
3.2	Can understand scope and constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.	The team understands the scope of the project as one with social, economic, health and safety benefits. Different constraints have been evaluated and solutions are being researched for them.
4.1	Can play different roles as a team player	Each member was easily able to switch from one responsibility to another responsibility as the need arose.
5.1	Identify engineering problems.	Checked feasibility and listed identified problems in data collection. Furthermore, deciding the scope was a major part of this.
6.1	Produce a variety of documents such as laboratory or project reports using appropriate formats.	Wrote SRS (Software Requirements Specification) along with an exhaustive project report which iterated throughout the duration of the project, following IEEE format. The report contains elaborate quantifications and

		explanations regarding the project.
6.2	Deliver well-organized and effective oral presentations.	Delivered a presentation of the product on multiple occasions (project evaluation sessions and idea defending) in front of a panel.
7.1	Write code in different programming languages.	Wrote code Python for ML modules. Many libraries and modules were also used.
7.2	Apply different data structures and algorithmic techniques.	Used arrays, dictionaries, hash maps, strings, etc. as per the requirements.
7.3	Use software tools necessary for the computer engineering domain.	Tensorflow, Pycharm, Open CV, Speech Recognition, and other Python libraries are extensively used.

7.7 Brief Analytical Assessment

Q1. What sources of information did your team explore to arrive at the list of possible Project Problems?

Ans: The group was aware of the understanding of the Capstone requirement and some of the problems that need to be explored. Team explored the literature, mostly the Technical journals and Technical magazines from IEEE. The interfacing issues have been refreshed through textbooks or internet resources. However, the scope has been decided after consulting our supervisor.

Q2. What analytical, computational and/or experimental methods did your project team use to obtain solutions to the problems in the project?

Ans: Constructing a simple and effective model was the most challenging task. We collected face data of various users and converted them into embeddings of size 128 and built models to detect the hand and the landmarks of the fingers. Deep Learning and various modules of Tensorflow are extensively used for building models.

Q3. Did the project demand demonstration of knowledge of fundamentals, scientific and/or engineering principles? If yes, how did you apply?

Ans: In this technical project, we have used the principles of Machine Learning and Voice Analysis. Other skills used are software integration techniques. Design, architecture and documentation principles were taught in the subjects Software Engineering and Software Design and Construction.

Q4. How did your team share responsibility and communicate the information of schedule with others in the team to coordinate design and manufacturing dependencies?

Ans: The team of five members divided the project into subtasks, individuals taking one subtask at a time. Slack, a free online project management tool was used to assign tasks, deadlines and for other communication and coordination. Besides we regularly connected physically to examine our progress.

Q5. What resources did you use to learn new materials not taught in class for the course of the project?

Ans: The team extensively utilized online tutorials, explored web resources, and referred to YouTube courses for hands-on learning and model implementation. Additionally, we delved into numerous papers and technical reports on IEEE, supplementing our class teachings with in-depth insights and cutting-edge materials. This diverse approach to self-education enriched our understanding of the topics central to our project.

Q6. Does the project make you appreciate the need to solve problems in real life using engineering and could the project development make you proficient with software development tools and environments?

Ans: The project confronts a tangible real-life challenge through engineering solutions, instilling in the team a profound appreciation for addressing practical problems. Engaging in this endeavor has not only heightened the team's awareness of the importance of solving real-world issues but has also sparked motivation to tackle diverse problems across various domains. The project served as a gateway to a spectrum of new technologies, exposing the group to cutting-edge advancements such as computer vision, deep learning, Raspberry Pi, and a range of Python libraries. This immersion in emerging technologies has broadened the team's skill set and fueled enthusiasm for embracing innovation in future endeavors.

APPENDIX - A: References

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APPENDIX - B: Plagiarism Report

DrillBit

The Report is Generated by DrillBit Plagiarism Detection Software

Submission Information

Author Name	Khushi
Title	Report
Paper/Submission ID	1237587
Submitted by	sjain@thapar.edu
Submission Date	2023-12-18 21:32:33
Total Pages	81
Document type	Synopsis

Result Information

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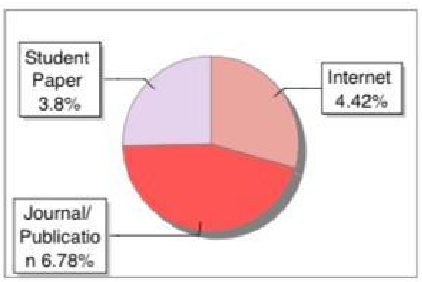

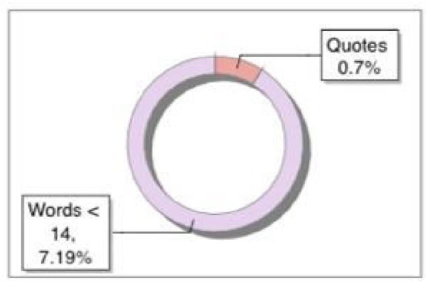

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