

# TPJ655 PROJECT REPORT

## FACIAL RECOGNITION-BASED DOOR ACCESS SYSTEM

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# 1. Executive Summary

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The Facial Recognition-Based Door Access System prioritizes security and convenience by implementing facial recognition technology, allowing authorized individuals seamless entry while enhancing overall access control.

With features such as a PIR Motion Sensor, real-time face comparison, LED, and LCD for easy of use by the clients, the system caters to diverse environments, including residential and commercial settings. The integration of administrator controls and real-time notifications further enables efficient user management and remote accessibility. This innovative system represents a significant step forward in access control technology, offering a secure and user-friendly solution.

# 2. Introduction

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Access control has been a persistent challenge in various environments, primarily relying on traditional key-based systems. These systems often expose vulnerabilities to security breaches and present inconveniences such as managing and carrying physical keys. In essence, they fall short of meeting the ever-evolving security needs of today's world.

The Facial Recognition-Based Door Access System is designed to enhance security and convenience in access control. Our project aims to provide an uncomplicated and highly secure means of access, offering authorized individuals a seamless entry while effectively preventing unauthorized access attempts. This technology-driven approach represents a promising enhanced security and convenience across a wide array of settings.

### 3. Functional Features

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This project addresses the growing need for robust access control systems in various environments, including residential, commercial, and institutional. It leverages affordable and widely available technology, making it accessible to a broad audience. The Facial Recognition-Based Door Access System offers the following key features:

- The system can detect human presence near the door using PIR Motion Sensor.
- In real time, the face will be compared with the images registered and stored in the directory.
- If the face matches one of the registered images, the door will be unlocked, and the “Access granted” message with the name of the registered visitor will be displayed on an LCD display. A green LED will be lit as well. The owner will be notified with the approved entry and the visitor's name.
- If the face does not match any registered image in the directory, the door will remain locked and at the same time, “Access denied” message will be displayed on the LCD. LED will remain Red.
- Furthermore, the visitor can press the button (buzzer) to notify the user. On pressing the button, the message sent confirmation is also displayed on LCD Display.
- The administrator can see the live feed displayed on the web interface and unlock the door remotely if the owner knows the visitor.
- The Administrator can register new individuals and add their names and images. Also, the Administrator can delete the existing individuals and their images by using the website.

## 4. Product Specifications

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### 1. Facial Recognition:

- Utilizes OpenCV for facial detection and recognition. Facial recognition runs in a thread for parallel processing.

### 2. Camera Module (PiCamera):

- The system captures frames using the Raspberry Pi HD camera Module (PiCamera) with a resolution of 640x480 pixels and Night Vision IR.

### 3. Motion Detection:

- PIR Motion Sensor for human presence detection.

### 4. Processing Unit:

- Raspberry Pi 4.

### 5. Website:

- HTML/CSS for the user interface.

### 6. Programming Language:

- Python with various libraries including Flask, picamera, OpenCV, face\_recognition, gpiozero, and RPi.GPIO.

### 7. Security Features:

- Electrical Door Lock: 12V solenoid, 500mA.
- RGB LED (5mm) for door lock status.
- I2C LCD Display (16 x 2) for real-time instructions.
- Button (Buzzer) for notifying the owner of property.

### 8. Power Consumption:

- Maximum Power Consumption: 10W.

### 9. User Interface:

- Web-based interface using Flask.
- Live-feed and remote access control of door lock.
- The interface allows adding or removing known faces.

### 10. Threads:

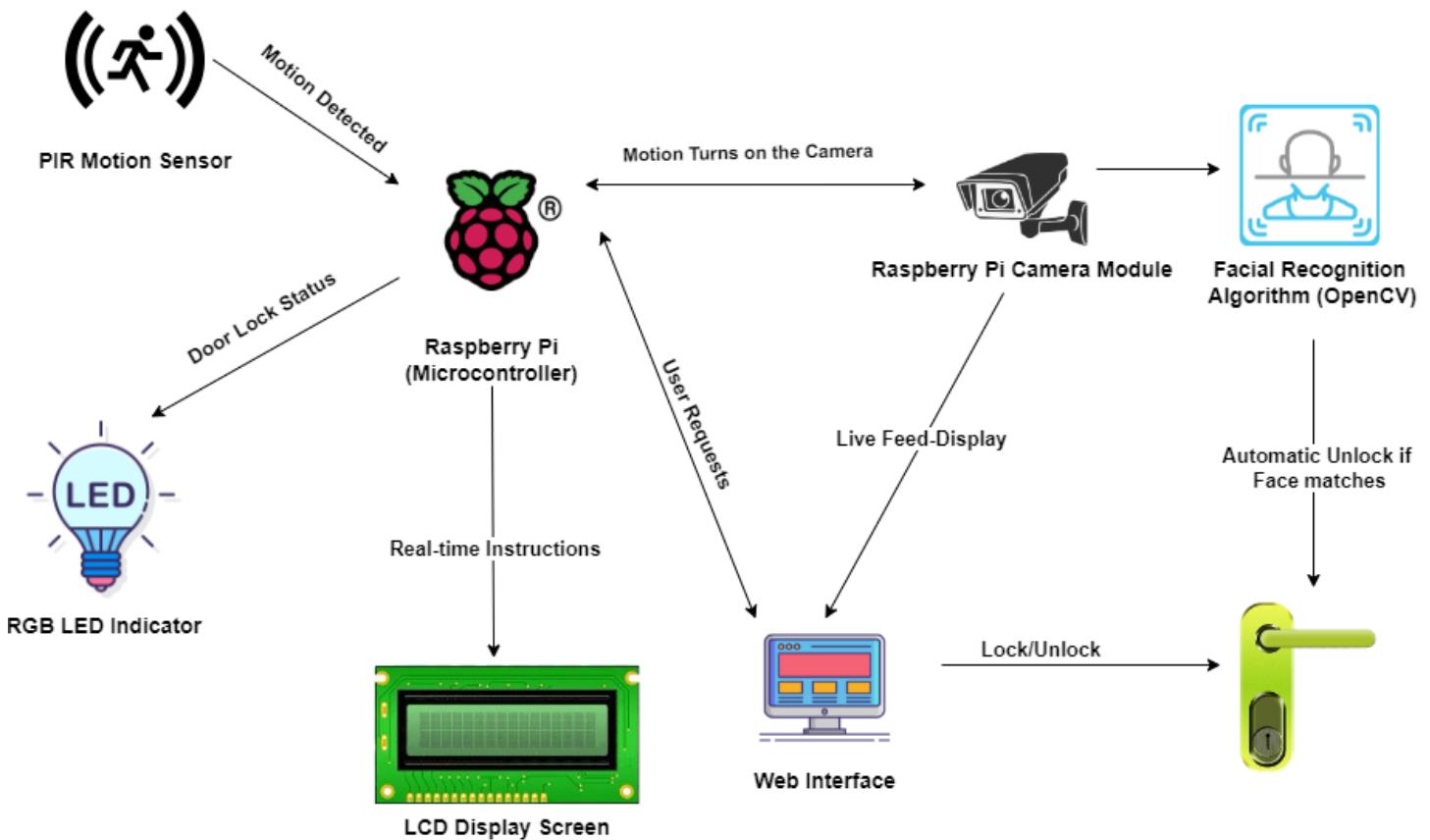
- Utilizes multiple threads for parallel processing, including Flask app, PIR motion detection, LCD display, LED control, and facial recognition.

## **11. Power Management:**

- Unlocks the door with a timer of 15 seconds.
- Power-efficient design with the ability to stop facial recognition when no motion is detected.
- Relay module to control and power the solenoid.

# 5. Product Design, Implementation, and Operation of the system

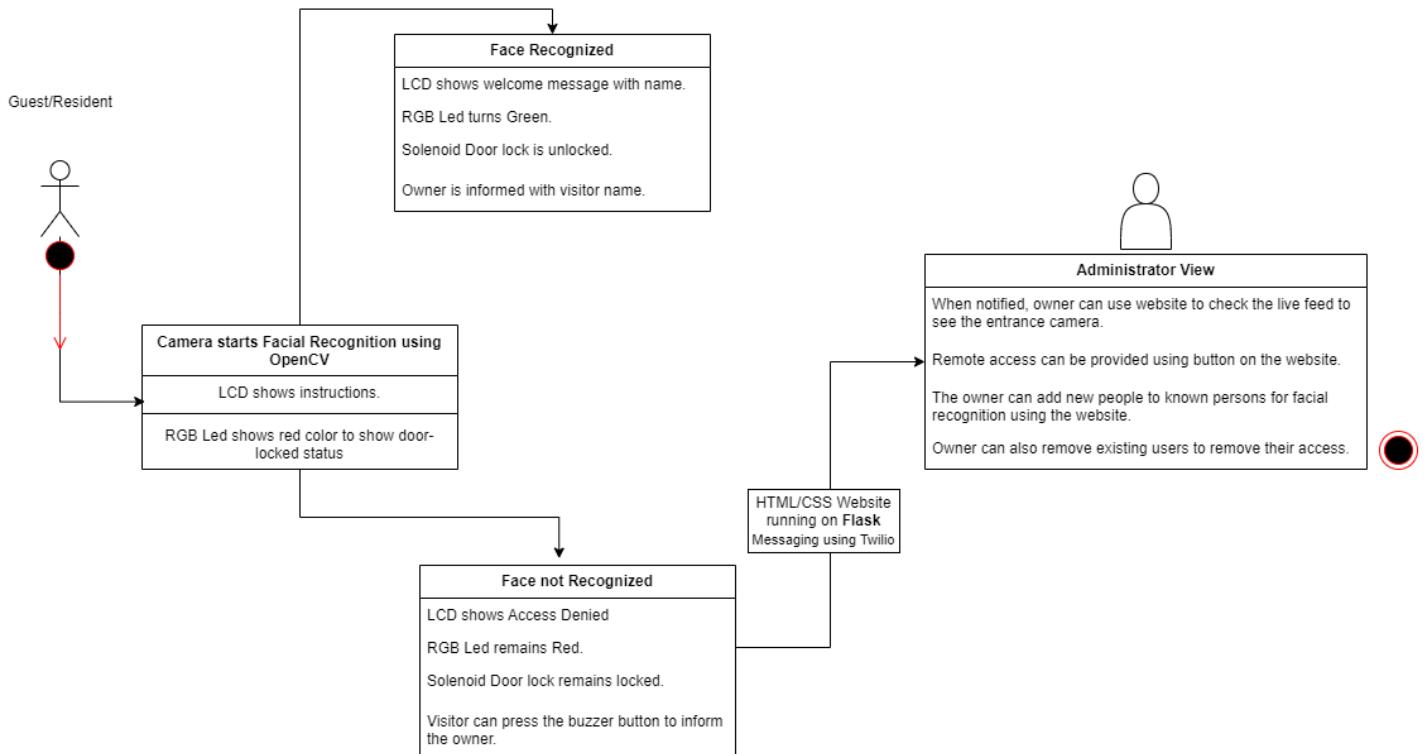
## ➤ Block-Diagram



The System Block Diagram provides a comprehensive visual representation of how different hardware and software components in the Facial Recognition-Based Door Access System achieve its functionality.

This diagram offers insights into the system's flow of information and control.

## ➤ Software-Diagram

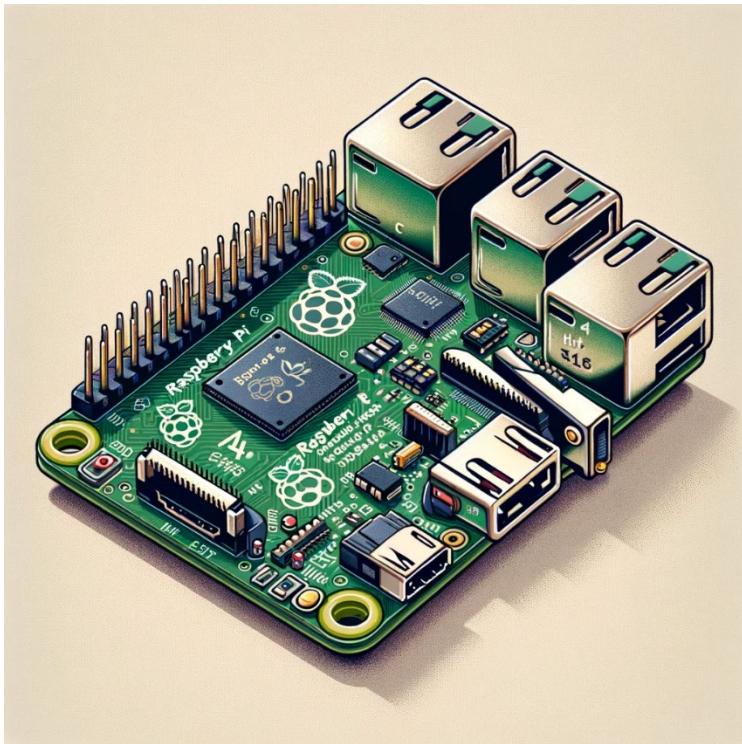


The system integrates facial recognition technology for secure access control, as depicted in the software diagram.

The web-based interface, powered by Flask, allows for user management. The software efficiently manages parallel processing threads for tasks such as motion detection, facial recognition, and user interface updates, ensuring a robust and responsive system.

➤ *Component Images and Description*

■ Raspberry Pi 4



**Component:** Raspberry Pi

**Description:** This single-board computer, developed by the Raspberry Pi Foundation, features a quad-core ARM Cortex-A72 processor, providing ample computing power for tasks such as camera control, facial recognition algorithms, and overall system coordination. With multiple USB ports, GPIO pins, and networking capabilities, the Raspberry Pi 4 seamlessly integrates with various components, including the camera module, motion sensor, and electrical door lock. Its compact design and versatile features make it a key component for seamless integration with various system elements, ensuring efficient access control operations.

## PIR Motion Sensor



### Component: PIR motion sensor

**Description:** The PIR motion sensor detects human presence near the door, serving as the system's motion detection component. This sensor triggers the facial recognition process when motion is detected, enhancing the security features of the access control system. This sensor can also be used to change the range and time of response by changing its distance and time knobs.

## Pi Camera Module

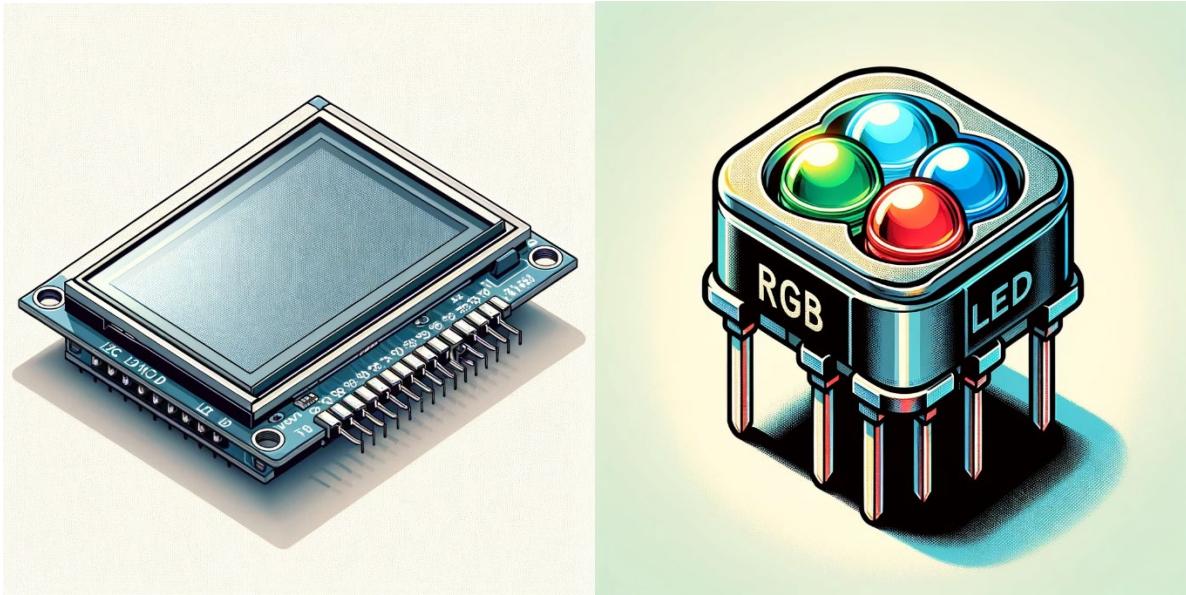


### Component: Raspberry Pi Camera Module

**Description:** The Pi Camera Module (OV5647) is a 5-megapixel camera integrated into the system for capturing frames. It plays a crucial role in the facial

recognition process, providing visual input for the system to analyze. With its compact form factor, night vision IR and high resolution (640 x 480 pixels), the camera module contributes to the system's effectiveness in recognizing faces and enhancing overall security with 100% accuracy.

## RGB LED and LCD Screen



### **Components:** RGB LED and LCD Screen

#### **Description:**

**RGB LED (5mm):** The RGB LED (5mm) is utilized to visually indicate the door lock status. With the ability to emit red and green colours, it provides a clear indication of whether the door is locked or unlocked. This component enhances the user interface and contributes to the overall user experience.

**I2C LCD Display (16 x 2):** The I2C LCD Display (16 x 2) serves as a real-time instructional interface, providing information about the system's status. With a two-line display and I2C communication, it offers a concise and readable output for users. The LCD display plays a key role in conveying messages, instructions, and feedback, enhancing the interaction between the access control system and users.

## Solenoid Door Lock



### Component: Solenoid Door Lock

**Description:** The Electrical Door Lock, powered by a 12V solenoid with a current of 500mA, is a crucial security feature of the system. It controls the physical access by locking and unlocking the door based on the facial recognition results. The solenoid's electrical mechanism ensures reliable and efficient door control, contributing to the overall security and access management of the Facial Recognition-Based Door Access System.

## Relay Module 5V



**Component:** Relay Module 5V

**Description:** The 5V Relay Module in the system functions as a switch specifically dedicated to powering the 12V solenoid. Operating on a 5V power supply, its primary role is to control and manage the electrical power supply to the solenoid, facilitating the seamless locking and unlocking of the door based on the system's commands.

 **Power Supply (12V)****Component:** Power Supply (12V)

**Description:** The 12V Power Supply is a dedicated power source in the system, providing the necessary voltage to operate both the Relay Module and the 12V solenoid. Serving as a vital component for the electrical door lock mechanism, this power supply ensures the reliable and consistent operation of the relay and solenoid, contributing to the overall functionality and security of the Facial Recognition-Based Door Access System.

## GPIO Breakout Expansion Board



**Component:** GPIO Breakout Expansion Board

**Description:** The GPIO Breakout Expansion Board for Raspberry Pi serves as a connector interface, expanding the General Purpose Input/Output (GPIO) capabilities of the Raspberry Pi. It simplifies the connection of various components in the system, including the RGB LED, solenoid, and relay module. This expansion board enhances the system's flexibility by providing organized and accessible GPIO connections, ensuring seamless communication and control between the Raspberry Pi and connected peripherals.

## ➤ GUI Captures

### 1. Putty Terminal: Started the Script and PIR Motion sensor triggered Facial Recognition.

```

pi@tpj12:~ 
pi login as: pi
pi@tpj12.local's password:
Linux tpj12 6.1.21-v8+ #1642 SMP PREEMPT Mon Apr  3 17:24:16 BST 2023 aarch64

The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
Last login: Fri Dec  1 17:17:14 2023
pi@tpj12:~ $ ./start_stream.sh
 * Serving Flask app "stream" (lazy loading)
 * Environment: production
WARNING: This is a development server. Do not use it in a production deployment.
Use a production WSGI server instead.
 * Debug mode: off
 * Running on http://0.0.0.0:5000/ (Press CTRL+C to quit)
Facial Recognition is in progress
[0]

```

Activate Windows  
Go to Settings to activate Windows.

### 2. Facial Recognition stops when no motion is detected.

```

pi@tpj12:~ 
pi login as: pi
pi@tpj12.local's password:
Linux tpj12 6.1.21-v8+ #1642 SMP PREEMPT Mon Apr  3 17:24:16 BST 2023 aarch64

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 * Serving Flask app "stream" (lazy loading)
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WARNING: This is a development server. Do not use it in a production deployment.
Use a production WSGI server instead.
 * Debug mode: off
 * Running on http://0.0.0.0:5000/ (Press CTRL+C to quit)
Facial Recognition is in progress
Facial Recognition completed
No motion. Stopping facial recognition.
Door is Locked
[0]

```

Activate Windows  
Go to Settings to activate Windows.

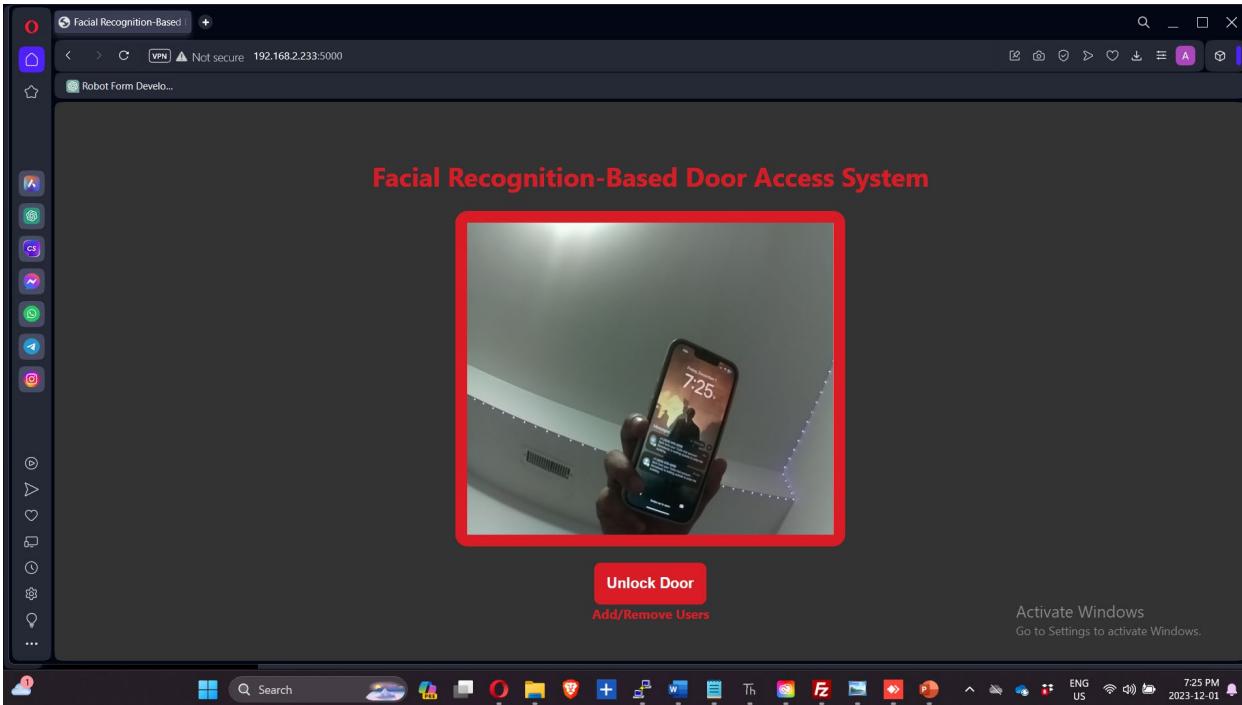
3. Face is not recognized, and the door remains locked to the Unknown person:

4. The unknown person used a button/buzzer to inform the Administrator/Owner:

5. The message was delivered successfully to the owner.



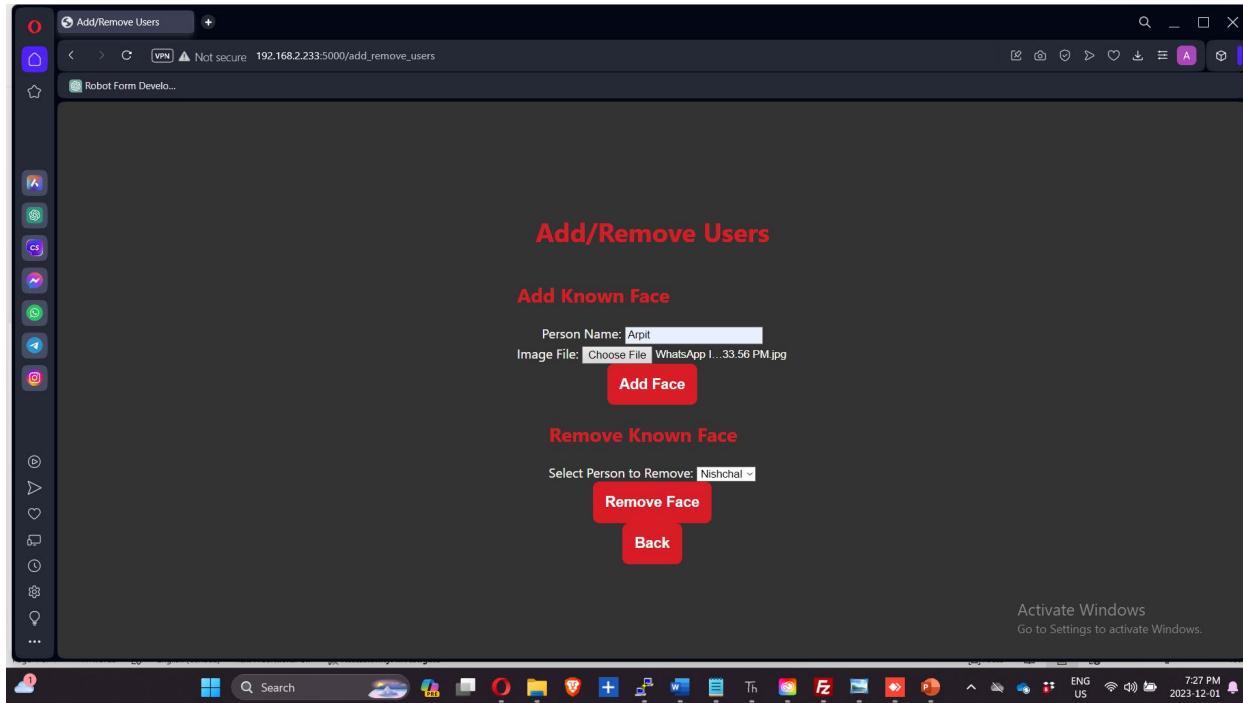
6. Owner launched website to check the live-feed.



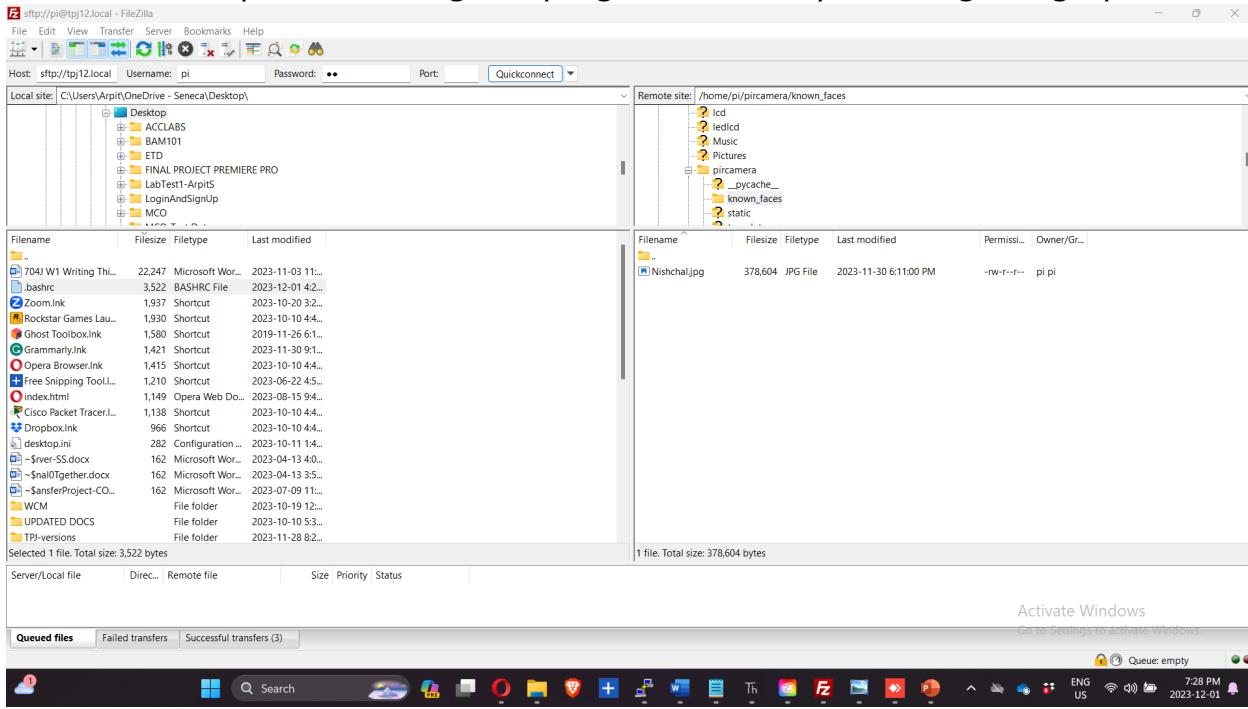
7. Owner provided access to the visitor using Unlock Door button on the website.

8. Door is automatically Locked after 15 seconds:

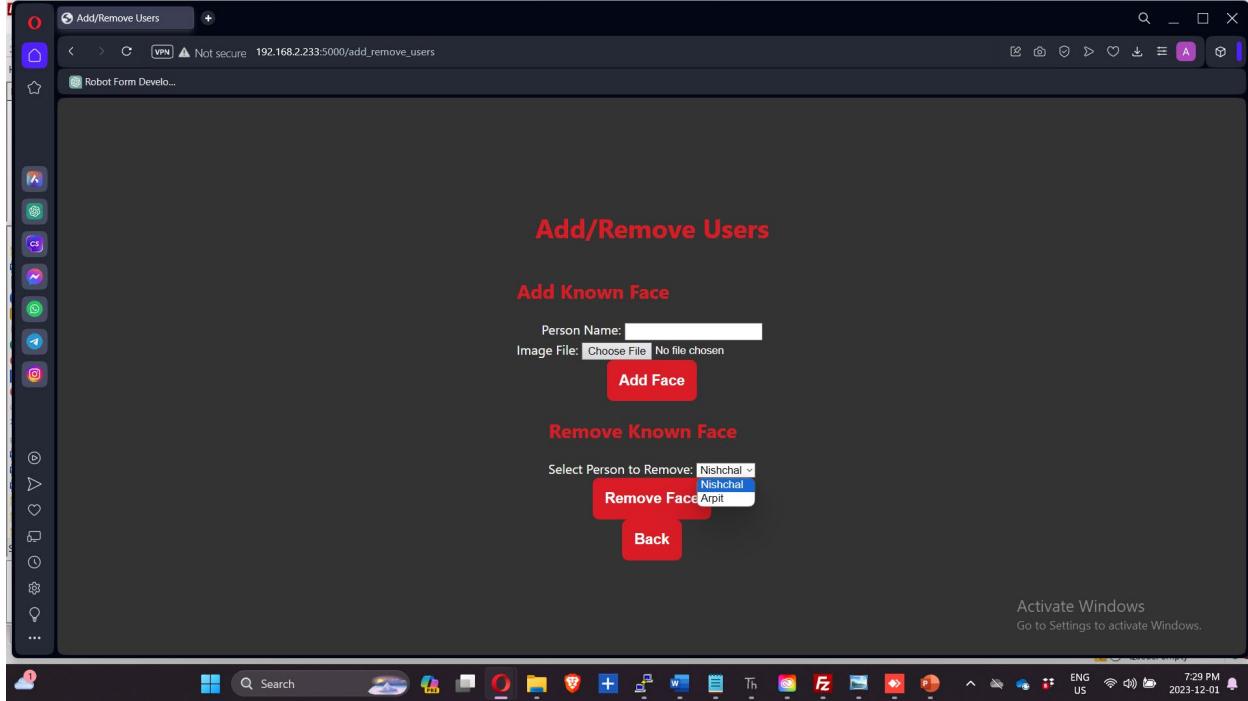
9. The administrator can add users by selecting the picture and entering the person's name:



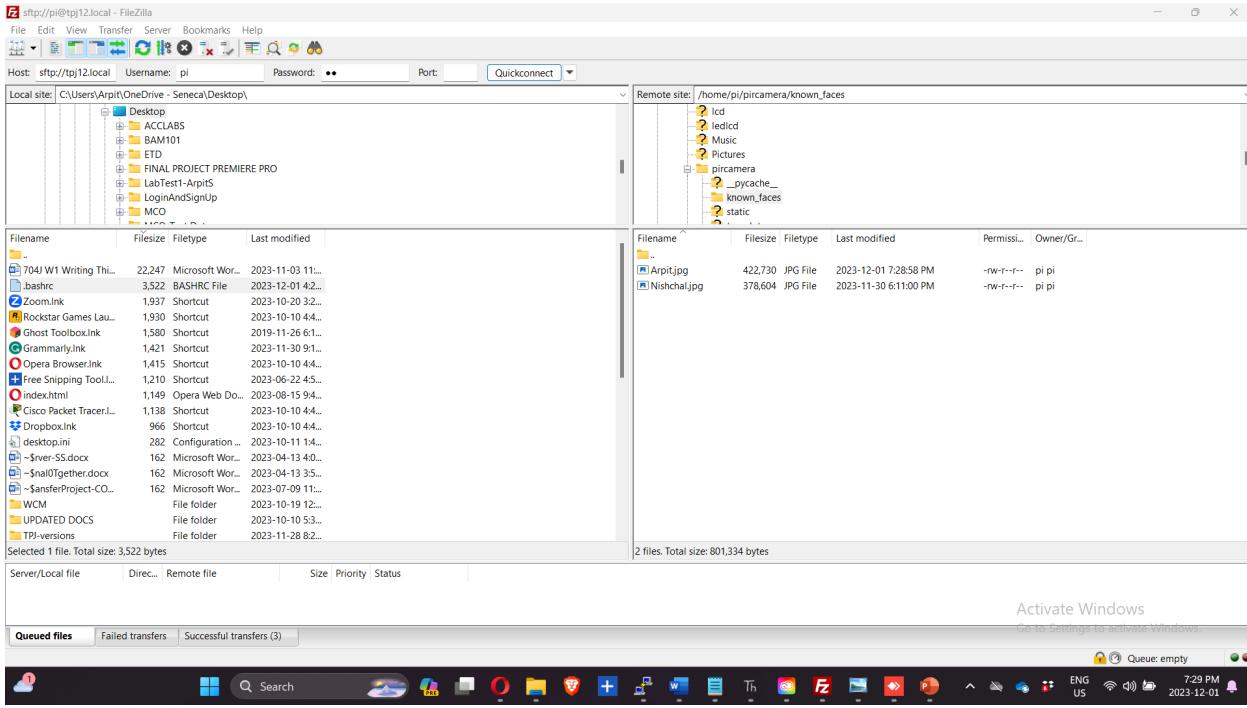
## 10. FileZilla capture showing the program directory before getting updated.



## 11. Capture showing the new face added successfully in the drop-down menu.



12. Capture showing the new face added successfully in the directory in real-time.



13. Terminal capture showing the new face was registered using the website.

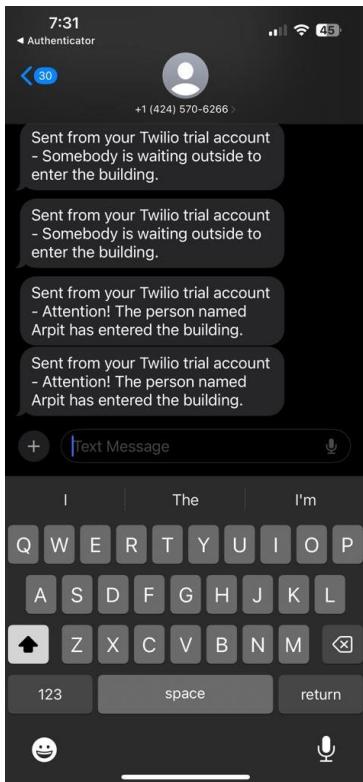
14. When the visitor again tries to unlock the door, this time the user was registered so the door unlocks.

```
p@tpj12: ~
Door is Locked
Facial Recognition completed
No motion. Stopping facial recognition.
Door is Locked
Facial Recognition is in progress
Button pressed! Message sent.
Facial Recognition completed
No motion. Stopping facial recognition.
Door is Locked
Facial Recognition is in progress
No motion. Stopping facial recognition.
Door is Locked
Facial Recognition completed
No motion. Stopping facial recognition.
Door is Locked
Facial Recognition is in progress
Button pressed! Message sent.
Facial Recognition completed
No motion. Stopping facial recognition.
Door is Locked
Facial Recognition is in progress
No motion. Stopping facial recognition.
Door is Locked
192.168.2.194 - - [01/Dec/2023 19:25:09] "GET / HTTP/1.1" 200 -
192.168.2.194 - - [01/Dec/2023 19:25:09] "GET /video_feed HTTP/1.1" 200 -
192.168.2.194 - - [01/Dec/2023 19:25:10] "GET /favicon.ico HTTP/1.1" 404 -
Door is Unlocked
192.168.2.194 - - [01/Dec/2023 19:26:26] "POST /unlock_door HTTP/1.1" 204 -
Door is Locked
192.168.2.194 - - [01/Dec/2023 19:27:20] "GET /add_remove_users HTTP/1.1" 200 -
192.168.2.194 - - [01/Dec/2023 19:27:20] "GET /static/style.css HTTP/1.1" 304 -
Facial Recognition is in progress
Facial Recognition completed
No motion. Stopping facial recognition.
Door is Locked
192.168.2.194 - - [01/Dec/2023 19:29:08] "POST /add_remove_users HTTP/1.1" 302 -
192.168.2.194 - - [01/Dec/2023 19:29:08] "GET / HTTP/1.1" 200 -
192.168.2.194 - - [01/Dec/2023 19:29:08] "GET /video_feed HTTP/1.1" 200 -
192.168.2.194 - - [01/Dec/2023 19:29:10] "GET /add_remove_users HTTP/1.1" 200 -
Facial Recognition is in progress
Facial Recognition completed
No motion. Stopping facial recognition.
Door is Locked
Facial Recognition is in progress
Door is Locked
Door is Unlocked
[]

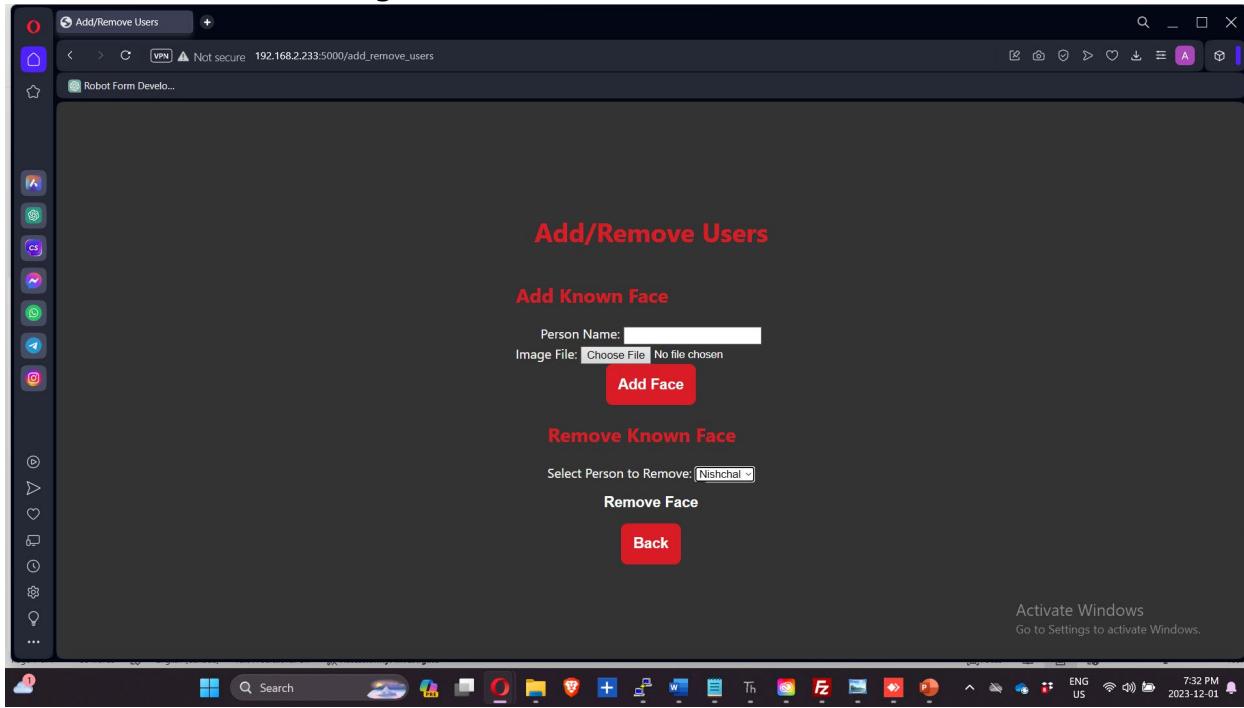
Activate Windows
Go to Settings to activate Windows.


```

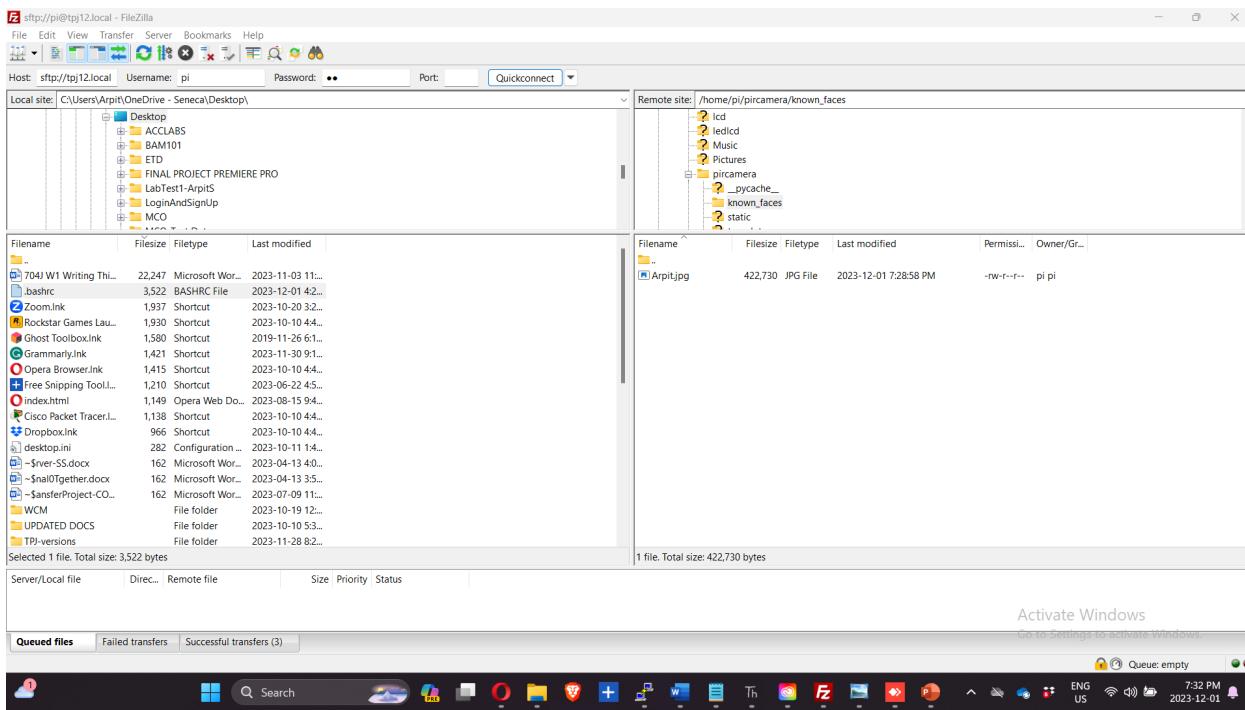
15. SMS with confirmation of the access provided is also sent with the name of the person.



16. The administrator can also remove the user by selecting the user from the drop-down menu and clicking on Remove Face.



17. FileZilla capture showing the selected user was removed successfully.



## ➤ *Theory of Operations of Entire System*

### **1. System Overview**

The Facial Recognition-Based Door Access System is designed to provide secure and intelligent access control. The system utilizes a Raspberry Pi 4 microcontroller as its central processing unit, connected to key components including a Pi Camera with night vision, I<sub>2</sub>C LCD display, solenoid door lock, and RGB LED. The intelligence of the system is driven by a Python script that initiates upon system power-up.

### **2. Known Person Access**

#### 2.1 Activation

- When a known person approaches the system, the PIR motion sensor detects their presence.
- The Python script starts running, initializing the facial recognition process.

#### 2.2 User Instructions

- The LCD display prompts the user to look into the camera.
- The RGB LED indicates the locked status with a red light.
- The solenoid door lock remains in a locked position.

#### 2.3 Access Granted

- If the recognized face matches the stored images, the door unlocks.
- The LCD displays an "Access granted" message with the name of the registered/authorized person.
- The RGB LED turns green, indicating authorized access.
- The owner receives a notification about the approved entry.
- The system is reset and door is locked after 15 seconds.

### **3. Unknown Person Access**

#### 3.1 Denial of Access

- For unknown faces, the system denies access.
- The LCD displays an "Access denied" message.

- The RGB LED remains red, signalling restricted entry.

### 3.2 Buzzer Feature

- Visitors can use the buzzer to notify the property owner.
- Pressing the button triggers a message sent confirmation on the LCD.

### 3.3 Remote Access Control

- The property owner can remotely view the live feed on a web interface.
- The owner can grant access by clicking the "Unlock" button on the webpage.

## 4. User Management

### 4.1 Adding Users

- Users can be added through the website by entering names and uploading pictures on the add/remove users webpage.

### 4.2 Removing Users

- Users can be removed from the directory by selecting them and clicking on the remove option on the add/remove users webpage.

### 4.3 Real-time Updates

- The system updates in real-time, reflecting changes in the user directory immediately.

## 5. System Flexibility

The Facial Recognition-Based Door Access System offers a flexible and dynamic solution for access control, addressing the need for robust security in various environments. The integration of real-time face recognition, remote access control, and user management through a web interface makes it a versatile and efficient choice for secure access control.

# 6. Maintenance Requirements

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## 1. Regular Inspection

- **Frequency:** Monthly
- **Tasks:**
  - ✓ Inspect all hardware components for physical damage.
  - ✓ Check wiring connections for any signs of wear or loosening.
  - ✓ Ensure the PIR motion sensor functions correctly.

## 2. Software Updates

- **Frequency:** Biannually
- **Tasks:**
  - ✓ Check for updates to the facial recognition algorithm or Python script.
  - ✓ Update the Raspberry Pi operating system and dependencies.
  - ✓ Ensure compatibility with the latest security protocols.

## 3. Database Management

- **Frequency:** As Needed
- **Tasks:**
  - ✓ Review and update the user directory as needed.
  - ✓ Add or remove users based on changes in access permissions.
  - ✓ Ensure the database is optimized for efficient face recognition.

## 4. Cleaning

- **Frequency:** Quarterly
- **Tasks:**
  - ✓ Clean the Pi Camera lens and sensors to maintain optimal image quality.

- ✓ Dust and clean the IP2C LCD display.
- ✓ Ensure the RGB LED is free from dirt or obstruction.

## 5. Power Supply Check

- **Frequency:** Annually
- **Tasks:**
  - ✓ Inspect the power supply unit for any signs of damage.
  - ✓ Verify stable power output to all components.
  - ✓ Replace power supply components if necessary.

## 6. Security Audits

- **Frequency:** Quarterly
- **Tasks:**
  - ✓ Conduct security audits to identify vulnerabilities.
  - ✓ Update access credentials and passwords.
  - ✓ Monitor and log access attempts for review.

## 7. Remote Access Testing

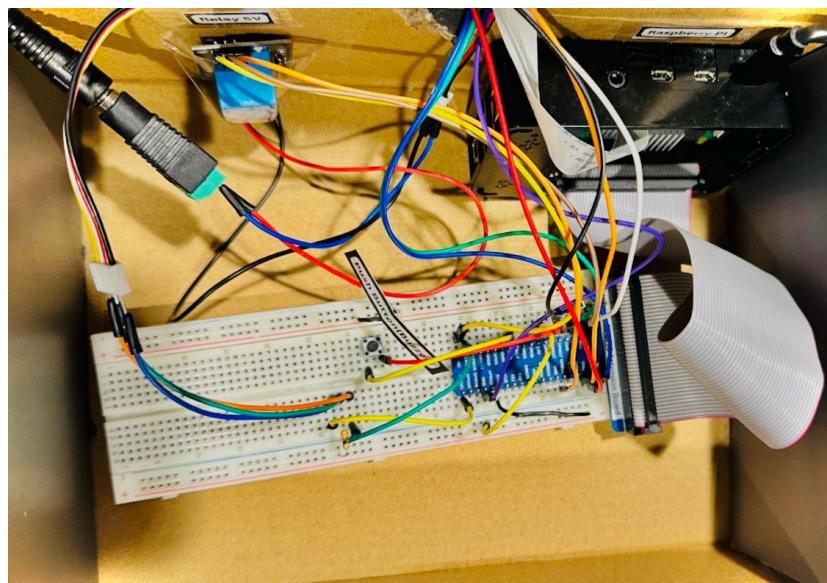
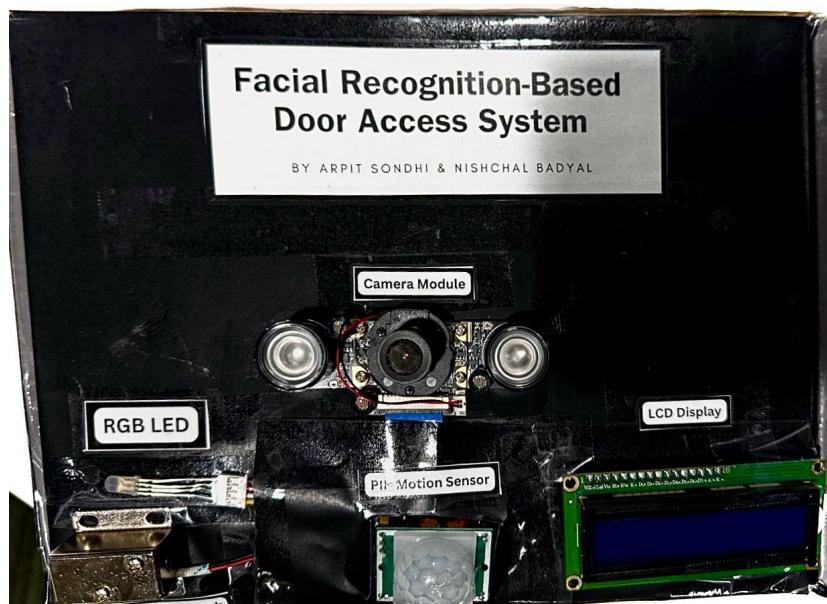
- **Frequency:** Biannually
- **Tasks:**
  - ✓ Test remote access functionality to ensure seamless operation.
  - ✓ Verify that the owner can access the live feed and control the system remotely.

## 8. Emergency Response Simulation

- **Frequency:** Yearly
- **Tasks:**
  - ✓ Simulate emergency scenarios to test the system's response.
  - ✓ Ensure the system notifies the owner promptly in case of unauthorized access attempts.

## 9. Backup and Recovery

- **Frequency:** Quarterly
- **Tasks:**
  - ✓ Perform regular backups of the user directory and system settings.
  - ✓ Test the restoration process to ensure data recovery capabilities.



## 7. Conclusion and Further Developments

### ➤ Conclusion

The Facial Recognition-Based Door Access System represents a significant leap forward in secure access control technology. By leveraging facial recognition algorithms and affordable hardware components, the system provides a robust solution for residential, commercial, and institutional settings. The successful implementation and testing of the system demonstrated its reliability in granting access to authorized individuals while effectively denying entry to unrecognized faces.

The integration of features such as real-time notifications, remote access control, and a user-friendly web interface enhances the overall usability and convenience of the system. The system's adaptability to different environments and user-friendly functionalities contribute to its practicality and accessibility.

### ➤ Further Developments

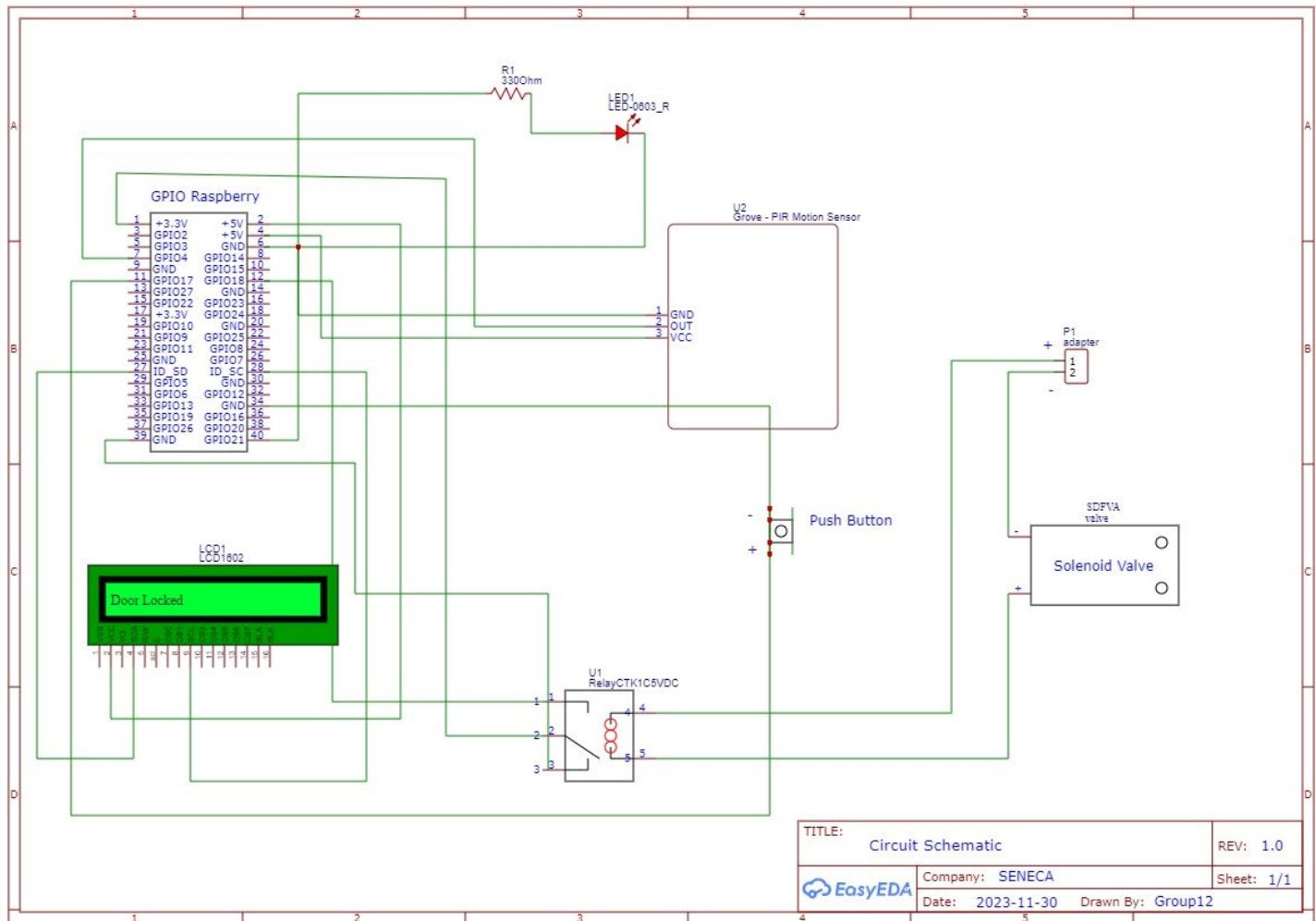
Although the current version of the system is effective, there's room for further development to make it even better and tackle new challenges. Here are some potential areas to focus on:

1. **Improved Facial Recognition Algorithms:** Looking into and incorporating more advanced facial recognition algorithms to boost accuracy and speed, especially in tricky lighting situations.
2. **Compatibility with Smart Home Systems:** Making the system compatible with existing smart home setups so that it can seamlessly work with other security and automation devices.
3. **Multi-Factor Authentication:** Implementing multi-factor authentication methods, like combining facial recognition with additional biometric or token-based verification.
4. **Enhanced Security Features:** Keeping security protocols up-to-date and strong to protect against evolving cyber threats and vulnerabilities.

5. **Machine Learning for Adaptability:** Adding machine learning capabilities to allow the system to adapt and learn from user behaviours, improving its performance over time.
6. **Energy-Efficient Hardware:** Explore energy-efficient hardware components to reduce power consumption and contribute to eco-friendly solutions.
7. **Cloud Integration:** Implementation of cloud-based solutions for remote access, management, and storage, allowing for scalability and accessibility from anywhere.
8. **Mobile Application:** Creation of a dedicated mobile application to provide users and administrators with convenient on-the-go access, notifications, and management capabilities.
9. **Increased Compatibility:** Exploring compatibility with diverse door mechanisms, including sliding doors, by incorporating alternative locking devices.

## 8. Appendix

### ➤ Electrical Schematic



## ➤ Bill of Materials

Name	Description	Qty	Price (cad)
Raspberry Pi	CanaKit Raspberry Pi 4 Starter Kit	1	\$199.99
PIR Motion Sensor	PIR Sensor Infrared Human Body Sensor Pir Motion IR Sensor Module	1	\$4
Raspberry Pi Camera	Camera Module for Raspberry Pi 4/3/2/B Wide Angle Fisheye Lens, 95 Degrees 5MP 1080P OV5647 with Night Vision	1	\$15
LCD Screen	IP2C LCD Display Module 5V with 16 Pins, Blue Display Screen Backlight 16x2 LCD Module Interface Adapter	1	\$16
RGB LED	RGB LEDs Water Clear Lens 5mm Common Anode Red Green Blue	1	\$0.20
Relay 5V	5V One 1 Channel Relay Module Board Shield with optocoupler Support High and Low-Level Trigger	1	\$5
Power Supply 12V	12V 2A Power Supply Adapter, AC 100-240V to DC 12V Transformers, Switching Power Supply	1	\$12.99
Solenoid Door Lock	DC 12V 0.4A 10mm Electromagnetic Solenoid Lock Assembly for Electric Lock Cabinet Door Lock.	1	\$21.99
GPIO Breakout board	Breakout Expansion Board, Compact GPIO Adapter High Working Efficiency Stability Practical Design Board	1	\$9.59
Breadboard	Electronics prototyping solderless board for assembling	1	\$10.65
Push button	Tactile Push button Switch SPST-NO Top Actuated Through Hole	1	\$0.16
	Total		Cad \$295.57

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- pi3g. "HOW TO Set up the Raspberry Pi Camera Module." YouTube, pi3g, <https://www.youtube.com/watch?v=yhM1NhD-kGs>.

## Images

- AI generated Images : <https://www.openai.com/research/gpt-3> Relay - relay 5v - [Search Images \(bing.com\)](#)
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- PIR Motion Detector Sensor Module Buy Online at Low Price in India - ElectronicsComp.com. [www.electronicscomp.com/pir-motion-detector-sensor-module-india](http://www.electronicscomp.com/pir-motion-detector-sensor-module-india).

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