THE DEVELOPMENT OF IOT BASED SMART DOOR LOCK AND FIRE ALERT SYSTEM USING FACIAL RECOGNITION

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ABSTRACT: The purpose of this study is to develop an IoT home security system that integrates facial recognition technology and offers remote access control. The proposed system integrates Raspberry Pi, a Raspberry Pi camera, a solenoid door lock and a flame sensor to offer advanced security features while ensuring user convenience. Operating within a cloud-based framework, users gain unparalleled accessibility to their home security. Through a mobile application, users can remotely monitor and control their door lock status from anywhere in the world. In order to enable smooth authentication upon detection, the technology makes it possible to save recognised faces inside the mobile application. Furthermore, the system enhances security measures by promptly notifying users of any unfamiliar faces detected. Beyond access control, the system prioritizes safety by incorporating a flame sensor. Upon detecting fire within the premises, the system activates, sending an immediate notification to the user and initiating automatic door unlocking. This critical feature ensures swift evacuation during emergencies, potentially mitigating property damage and ensuring occupants safety.

KEYWORDS: *IoT Home Security; Remote Access Control; Flame Sensor; Smart Door*

Lock

1.0 INTRODUCTION

Home security has become a prime concern in today's society. With the rise of urbanization and increase crime rate, the universal need for intelligent and effective security system is growing [1]. In recent years, smart home technology has improved a lot and leading to more automation and better household system [2]. One of the most important features of smart home devices is the door that can be lock from remote location beside the self-adjusting thermostat [3].

Internet-of-Things (IoT) is also known as Machine-to-Machine (M2) is refers to interconnected devices that communicate and interchange data through the internet adhering to specific protocols [4-5]. The primary goal of IoT is to connect smart devices with sensor, processors and communication tools to collect, share and respond to information form the surroundings [6]. IoT-based smart door is modern way to keep houses safe it enables security system to provide unparallel convenience to the homeowner where they can monitor their home security from almost everywhere [7]. One of the most important part of any home security system is accurately detecting visitor who enter and leave through the door [8]. Beside that face recognition can help the security problems and build a more advance environment at the same time [9]. It is popular among other biometric methods because of it is accurate, reliable and easy to use [10]. Therefore, in this study, we proposed an IoT-based smart door lock using facial recognition. Despite advancements in home security technology, traditional methods of securing homes, such as locks and key. Key-based entry systems can be lost, stolen or duplicated, compromising the safety of households [11]. Additionally, these systems lack the ability to adapt to dynamic security needs and provide real-time alerts in case of unauthorized access or emergencies.

Moreover, existing smart door lock systems often rely solely on keypad codes or keycard access, which can still be susceptible to unauthorized entry if codes are compromised or cards are lost. Fingerprint or biometric systems can be easily hacked or bypassed [12]. These systems also lack the capability to distinguish between authorized and unauthorized individuals, leading to potential security breaches. Recognizing these limitations, there is a growing demand for a more robust and intelligent home security solution that combines the convenience of remote access control with advanced authentication

and safety methods, such as facial recognition. There's a crucial need for enhanced safety measures within households, particularly regarding fire hazards. Traditional security systems often lack mechanisms to detect and respond to fire emergencies swiftly. By integrating fire detection capabilities into the smart door lock system, households can benefit from immediate alerts and automatic unlocking of doors in the event of a fire, ensuring timely evacuation and mitigating potential risks to occupants.

Therefore, the problem addressed in this research paper is the need for an IoT-based smart door lock system with facial recognition capabilities that enhances home security while providing users with convenient access control and real-time alerts for unauthorized access and emergencies and also the safety method for fire alert system.

2.0 PROBLEM STATEMENT

Most existing security systems do not offer the ability to monitor or control access remotely and poor security management performance [13]. This means that homeowners cannot check the status of their doors or lock them from afar, which can be problematic if they forget to secure their home or need to grant access to someone in their absence. As remote work becomes more common and people's lives get busier the inability to monitor and control some security remotely has become a major issue [14]. Additionally, many home security system face challenges such as delays and alert transfer during unusual events. [15]. The lack of real-time control and monitoring limits the effectiveness of these systems and can leave homes vulnerable to security breaches.

Another significant limitation is that traditional systems generally do not offer any form of advanced identification or emergency response. They are unable to recognize or verify individuals attempting to enter the home. Without the capability to distinguish between familiar faces and strangers, these systems are unable to provide security responses. Allowing friends or family members to unlock the door without the key when no one is present is not possible [16]. Furthermore, traditional systems do not have built-in mechanisms to handle emergencies like fires. In the event of a fire, these systems do not alert the homeowner or assist in safe evacuation, which can be a critical flaw. To address these shortcomings, there is a growing need for a home

security system that integrates modern technology with advanced safety features. An ideal system would offer facial recognition to accurately identify individuals, allowing only authorized people to gain access. Additionally, it would provide the capability for remote monitoring and control, enabling homeowners to manage their security from anywhere. This system should also include emergency features, such as fire detection, to ensure quick response and safe evacuation during crises.

3.0 LITERATURE REVIEW

Researchers in [17] proposes a new model for door locking and unlocking by detecting faces. The system captures live video from a web camera and processes the images through a Raspberry Pi3 and checks them with a stored database. A keyboard and display board are connected to the microcontroller, which controls the motor driver to lock and unlock the door. The system includes an alternate manual passcode unlocking system by using a keypad. The authors use the LBPH algorithm, as it provides more accurate results when compared to other algorithms. The proposed model has a drawback, as it requires a person to have their face recognized before they can gain access to the door. If there are any issues with the facial recognition, the user will not be able to access the door. However, this approach is considered the most secure, and without a matching face and the passcode, no one can access the door.

The study by [18] proposes an automatic door lock system utilizing the Raspberry Pi3, pi camera and a dc motor. The system captures images using the Harr cascade algorithm and unlocks the door for recognized faces. It connects to a system database and open-source home automation platforms via python. The drawback of this system is that it has a high false detection rate, which can result in security breaches. The use of PCA can help reduce the false detection rate; however, it increases computational complexity and development cost. Additionally, the system has limitations in recognizing faces at night or in low light conditions.

Studies such as [19] discusses an IoT-based door lock system called "The Viola-Jones Face Detection Technique Wireless IoT Smart Door Lock." The study focuses on using face detection algorithms for smart door locks. It employs automatic feature extraction of photos and machine learning through Viola-Jones. A Wi-Fi camera captures the

user's face for door access, which is then saved in a training set. Principal Component Analysis (PCA) in OpenCV completes facial feature extraction. The system unlocks the door if the input face matches the training dataset, triggering an alarm otherwise. While effective in preventing unauthorized access, it lacks remote management capability and monitoring, causing potential inconvenience for users.

The approach in [20] propose an intelligent door lock system using the Raspberry Pi and Android app. The system captures the visitor image and uses images for access and sends unknown visitor image to the homeowner device for remote approval. It connects with the firebase for real time updates. However, the system has key safety flow, it lacks any fire detection or alarm features, which could endanger users during emergencies.

4.0 SYSTEM ARCHITECTURE

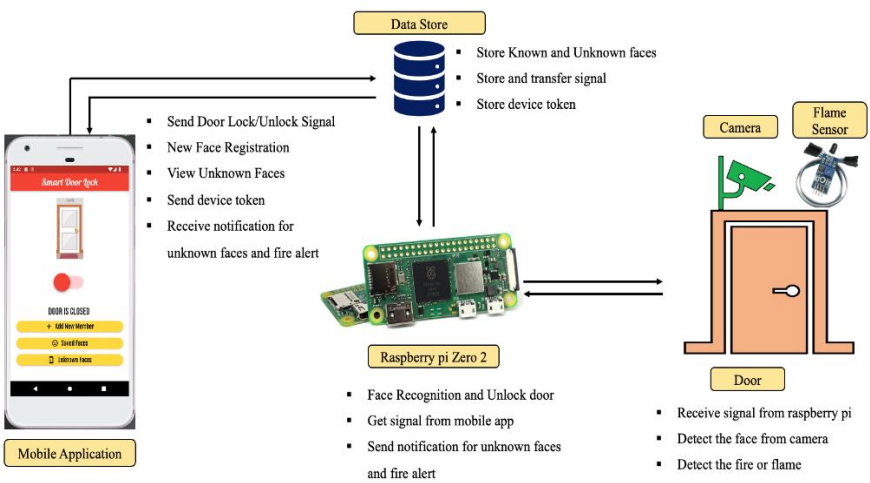


Figure 1: The proposed system architecture

The proposed system architecture for the system integrates five main components: the Raspberry Pi, Raspberry Pi camera, flame sensor, solenoid door lock and relay. This architecture combines hardware elements to create a comprehensive home security solution that incorporates facial recognition technology and fire detection

capabilities.

i. Mobile Application: The mobile app enables remote door control, allow user to add new faces for face recognition and display images of unrecognized persons and receive notifications if the system detects unknown person or any fire alert. Additionally, the mobile app sends a unique device token to the system, which is used for authentication and secure communication between the mobile app and the door lock system.
ii. Data Storage: The system's data storage is responsible for records image if known and unknown faces, unknown visitor log information. Along with that, the data storage also handles signals sent from the mobile app, such as lock/unlock commands, and saves the device tokens used for authentication.
iii. Raspberry Pi: The Raspberry Pi handles all major tasks such as facial recognition, mobile app communication and door control. It processes the video input form the pi camera to recognize faces, unlocking the door for authorized users and notifying the app for unknown visitors. It also responds to lock/unlock commands and fire alerts form the flame sensor.
iv. Door Components: The solenoid door lock and relay relay receive signals form the Raspberry Pi to lock or unlock the door based on the facial recognition results, app commands and flame sensor alerts. The relay acts as a switch to operates the lock.
v. Flame Sensor: The flame sensor detects fire and sends alerts to the Raspberry Pi for the fire hazards then the Raspberry Pi sends an emergency notification to the mobile app and unlock the door for safety.

This proposed architecture stands out due to its combination of facial recognition technology for security and fire detection for safety. The use of a Raspberry Pi makes the system cost-effective and easy to customize. Additionally, integrating a mobile app allows for remote control and monitoring, giving users full control over who can access their home.

5.0 METHODOLOGY

This project integrates both hardware and software to develop the system, with a Raspberry Pi serving as the main controller due to its processing power, library support and ability to handle real-time image processing efficiently compared to alternative like Arduino or ESP32. Facial recognition is implemented using the face_recognition

library with the histogram of oriented gradients (HOG) method, selected for its balance between computational efficiency and accuracy without requiring high-end GPUs. A solenoid lock is employed for door control, preferred over the electromagnetic locks for its energy efficiency and secure locking mechanism and also integrates a flame sensor capable of detecting the infrared light emitted by fires. The entire system is connected to Google Firebase, which allows for real-time updates and remote control through a mobile app. This setup lets users monitor and control the system from anywhere, making it both secure and convenient.

The development process begins with the utilization of the face_recognition library to enable facial recognition-based access control. This involves continuously capturing frames from a webcam feed and employing Histogram of Oriented Gradients (HOG) methodology to detect faces within each frame. These detected faces undergo encoding into 128-dimensional numerical vectors, enabling the creation of unique representations of facial features. Upon encoding, the system compares detected faces with known faces stored in its database, utilizing Euclidean distance calculations to determine matches accurately. Upon successful recognition, the system triggers various predefined actions, including displaying the recognized individual's name, unlocking the door via GPIO pins and sending notifications to a designated mobile application to indicate access approval. In the event of an unrecognized face, the system captures images for further analysis and promptly notifies users of potential security breaches, ensuring proactive security measures. Additionally, the system integrates seamlessly with Firebase for real-time database updates.

In addition to its core functionalities, the system seamlessly integrates a flame detector into its framework. This flame sensor is specifically designed to detect the presence of fire by recognizing infrared light, which is emitted by flames. The sensor consists of an infrared (IR) receiver that can detect the particular light wavelengths that come from fire. When the flame sensor detects a flame, it generates an analog signal that corresponds to the intensity of the detected infrared light. The inbuilt circuitry of the sensor then processes this signal, transforming it into a digital signal that the Raspberry Pi can read. The sensor is attached to a GPIO pin on the Raspberry Pi, which enables the microcontroller to receive the signal when a flame is detected. Once the Raspberry Pi receives this signal, it immediately triggers a series of

actions. First, it activates the GPIO pins that control the solenoid door lock, unlocking the door. This automatic response allows people to exit quickly during a fire emergency, adding an important safety feature. At the same time, the Raspberry Pi sends a notification to the user's mobile device through Firebase. Moreover, the system is designed to relay real-time alerts to the user's device, empowering them with crucial information to take necessary actions.

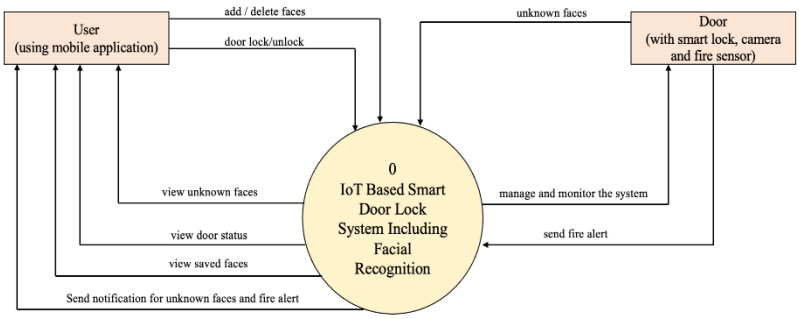


Figure 2: Context diagram

The IoT-based Smart Door Lock System, including facial recognition, is deployed in a cloud-based framework and is accessible via a mobile application, as depicted in Figure 3. The development environment involves configuring the hardware, software, and network components. Users interact with the system through a mobile app, which communicates with the system's database. The system relies on a MySQL database for data storage, while the integration with Google Firebase supports real-time database updates and notifications. As shown in Figure 3, users can access the system through their mobile devices, utilizing the mobile application to control and monitor the system remotely. The data flow involves users accessing the system via SDKs for Android or iOS (apk/ipa files), which communicate over HTTP using JSON format to send requests to the live server. This server then interacts with the live database and Google Firebase, ensuring that the system functions efficiently and that users receive timely updates.

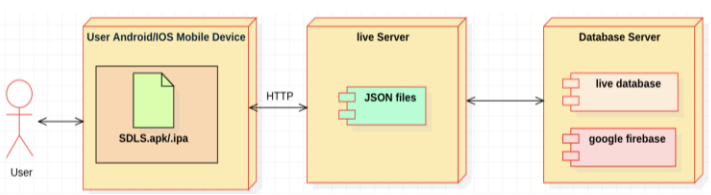


Figure 3: Deployment Diagram

6.0 RESULTS AND DISCUSSION

The proposed system has successfully achieved its goals of providing a secure and convenient way to control access to a home. The system effectively recognizes authorized faces, using a camera it continuously captures images of people approaching the door. If a match is found, the system automatically unlocks the door by sending a signal to the solenoid lock using the Raspberry Pi's GPIO pins. If the system detects a face that is not in the database, it captures an image of the person and sends an alert to the user's mobile app with the picture of the unknown face. This alert allows the user to be aware of any potential unauthorized access attempts. This proactive security measure enhances the overall safety of the home by ensuring that the user is always aware of who is trying to enter. The performance of the facial recognition was evaluated using the following formula.

$$\text{Known Face Detection Success Rate (\%)} = \left(\frac{Successful\ Known\ Detections}{Total\ Known\ Frames}\right) \times 100$$

$$\text{Unknown Face Detection Success Rate (\%)} = \left(\frac{Successful\ Unknown\ Detections}{Total\ unknown\ Frames}\right) \times 100$$

The system demonstrated a Known Face Detection Success Rate of 100% and an Unknown Face Detection Success Rate of 99.51%. And the Receiver Operating Characteristic (ROC) curve evaluated the model's ability to distinguish between the known and unknown faces. AUC is 1.00, indicate the perfect classification and a vertical curve rise and flat plateau at 1.0 signify no false positives and complete true positive detection in Figure 4.

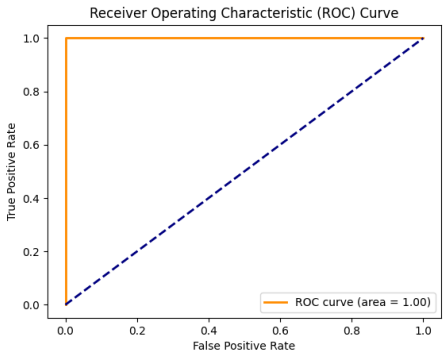


Figure 4: Receiver Operating Characteristic (ROC) Curve

In addition to facial recognition, the system integrates a flame sensor to detect fires. When the sensor detects a flame, it sends a signal to the Raspberry Pi. The system then triggers an automatic response to unlock the door, allowing people to exit quickly and safely during a fire emergency. At the same time, it sends an alert to the user's mobile device, notifying them of the fire. The flame detection response times were measured and the results shown a mean of 0.000027s, a median of 0.000026s and standard deviation of 0.000004s. The response times ranged from a minimum of 0.000015s to a maximum of 0.000045s. The response time are highly consistent, with a mean of 0.000027 and minimal variability. The histogram in Figure 5 shows a normal distribution of response times centred around the mean, while the time series graph in Figure 6 indicates stable sensor performance over time.

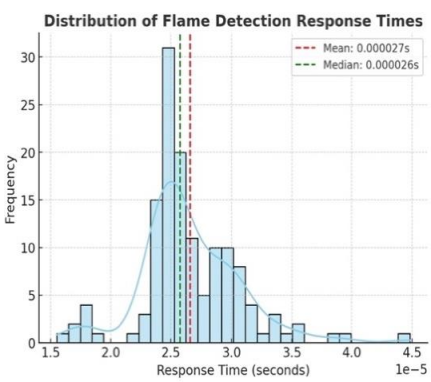


Figure 5: Distribution of flame detection response times

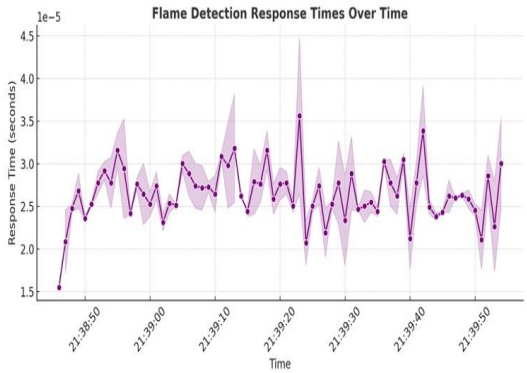
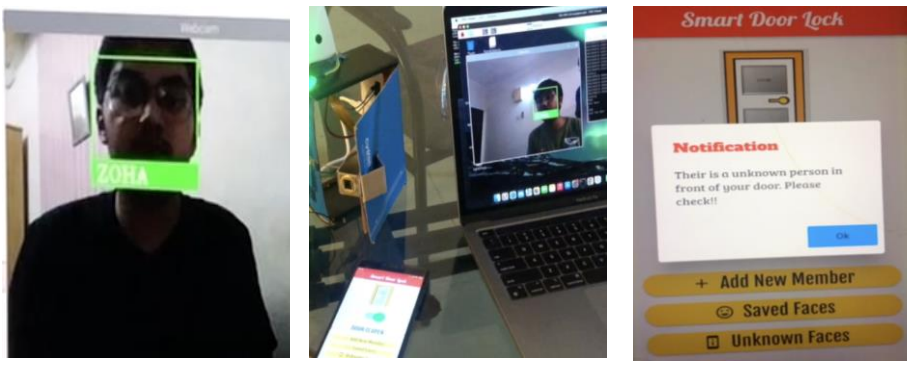


Figure 6: Flame detection response times over time

Overall, the proposed smart door lock system combines facial recognition and fire detection to create a comprehensive security solution. It ensures that only authorized individuals can enter the home while also providing a quick response to fire emergencies. The ability to send real-time alerts to the user's mobile device enhances the system's effectiveness, allowing the user to stay informed and take immediate action when necessary. By combining advanced technology with safety features, the system provides a reliable way to protect both the property and the people inside the home.

7.0 EXPERIMENTAL RESULT



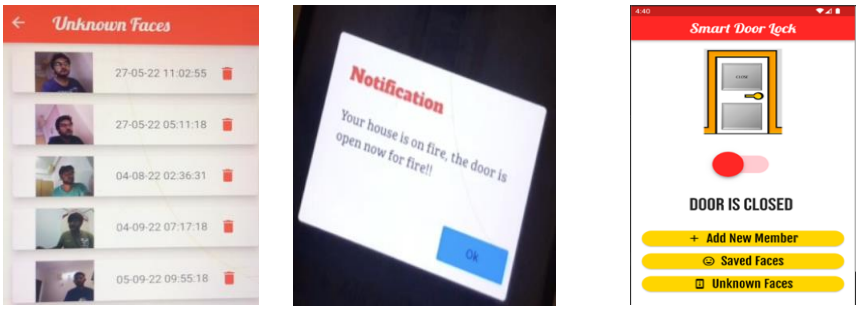
(a) (b) (c)

Figure 7: (a) Face Detected, (b) Face detect and unlock the lock, (c) Unknown Face Notification

After thorough testing, the system recognized authorized individuals,

unlock the door, and let them in. The Figure 7(a) and 7(b) shows the detection of known faces and unlock the door.

If someone unknown approached, Figure 7(c) and 8(a) shows that it sent a notification to the user's phone with a picture, allowing them to act fast.



(a) (b) (c)

Figure 8: (a) Unknown Faces Picture in App, (b) Fire Alert Notification, (c) Mobile App Interface

It also had a fire sensor that alerted the user and unlocked the door during emergencies. Figure 8(b) shows the alert one the user mobile application for the fire alert. And Figure 8(c) shows that users could check if the door was open or closed in real-time. These tests prove the system is effective for home security, providing reliable access control, alerting about potential risks, and monitoring the door's status.

8.0 CONCLUSION

In conclusion, the system focuses on improving the home security. The main problems addressed are unauthorized access and fire hazards. The proposed solution integrates facial recognition to grant access only to the authorized users and sends instant alert when unknown faces are detected. A fire detection feature identifies hazards and automatically unlocks the door for a quick exit. Remote access via a mobile app enhances the user convenience with real-time control and notifications. Experimental results show that the system effectively improve security and emergency response. For future work, improvements can be made by integrating a backup power supply for the Raspberry Pi and expanding system compatibility with other home devices for seamless automation.

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