Face Recognition and Raspberry Pi Powered Smart Door Unlocking System

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Abstract. Security plays a major role in the well-being of people. It is not possible to hire a security guard in person and always ensure his presence on our premises. It is an inefficient investment. The main role of security personnel is to stay on patrol, monitor, inspect and defend against any breach of security. A smart lock is an electromechanical lock that allows entry based on the authorization device that gives it instructions to lock and unlock. This system is proved to be inefficient as well These locks are either based on Pin, Bluetooth, WIFI. We propose a smart locking system that unlocks based upon face recognition that pic up specific, distinctive details about a person's face. This is a powerful library that can run even by taking up a single picture of the person provided that the facial features are distinctly identified. The model is proven to be reaching accuracy levels of 99.7% according to the Centre for Strategic and International Studies (CSIS). The database is stored on the cloud consisting of all the authorized personnel that can pass through the door. The client holds the power of customizing the entry and exit of an individual through an application on his mobile.

Keywords*: Automation, Face Recognition, Deep Learning, Machine Learning, Raspberry pi, Solenoid lock, Haar Cascade Classifier.

1 Introduction

The demand for secure and convenient door-locking systems has increased significantly in recent years. Conventional lock and key systems are becoming outdated and unreliable, making exploring new technologies that offer greater security and convenience is necessary. One such technology is face recognition, which has proven to be an effective biometric authentication method for identity verification. Raspberry Pi is a small and affordable computing device that can be used to develop innovative and cost-effective solutions for various applications. This research paper proposes a customized smart door unlocking system that uses face recognition technology on a Raspberry Pi platform. The system is designed to offer secure and convenient access control by authenticating the identity of the user based on

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their facial features. We aim to evaluate the performance of the system by conducting experiments and the results obtained. This research presents a novel solution that combines the benefits of face recognition and Raspberry Pi to address the challenges of door-locking systems

2 Literature Survey

Facial recognition has been extensively studied and applied in various fields, including security, biometrics, and human-computer interaction [1]. Researchers have proposed various algorithms and techniques to improve the accuracy and efficiency of facial recognition systems. One of the most widely used techniques is the Haar Cascade Classifier, which uses machine learning algorithms to detect the presence of specific facial features [2]. The Haar Cascade Classifier has been applied in various access control systems, including door locks, attendance systems, and surveillance systems. However, the accuracy of the Haar Cascade Classifier depends on the quality of the training data and the selection of appropriate features [3]. Therefore, researchers have investigated the use of deep learning and convolutional neural networks (CNNs) to improve the accuracy of facial recognition systems. These techniques have shown promising results in detecting and recognizing faces with high accuracy, especially in challenging environments with low illumination or occlusion [4]

In addition to facial recognition techniques, researchers have also investigated the use of Raspberry Pi boards in access control systems. Raspberry Pi is a low-cost, credit card-sized computer that can be easily integrated with various sensors and electronic devices [5]. It has been widely used in various applications, including home automation, robotics, and IoT. The use of Raspberry Pi in access control systems provides several benefits, including low cost, ease of integration, and flexibility [6]. Researchers have proposed various approaches to integrating Raspberry Pi with access control systems, including the use of Wi-Fi or Bluetooth for communication, the integration of sensors for environmental monitoring, and the use of cloud-based services for remote management. However, the integration of Raspberry Pi with facial recognition techniques is still an area of active research [7].

Solenoid locks have been widely used in access control systems due to their high reliability, low cost, and ease of installation. Solenoid locks are electronically controlled locks that can be easily integrated with access control systems, providing a more secure and convenient way of accessing secured areas [8]. Researchers have proposed various approaches to integrating solenoid locks with access control systems, including the use of RFID cards or PIN codes for authentication, and the integration of sensors for environmental monitoring [9]. However, the use of solenoid locks in combination with facial recognition techniques is still an area of active research [10]. Researchers have investigated the reliability and durability of solenoid locks, especially in high-traffic areas, and have proposed various approaches to improving the security of solenoid locks, including the use of encryption and other security measures [12]. Therefore, the proposed research aims to integrate the benefits of facial recognition techniques, Raspberry Pi boards, and solenoid locks in a customized smart door unlocking system, providing a more secure and efficient access control system [13].

3 Proposed system

The proposed smart door unlocking system is designed to provide a secure and convenient access control solution using face recognition technology on a Raspberry Pi platform. The system consists of a Raspberry Pi board, a camera module, and a face recognition algorithm

[14]. The camera module captures an image of the user's face, which is then processed by the face recognition algorithm. The algorithm extracts facial features and compares them with the stored face templates to determine whether to grant access or not. The system is designed to be customizable and can be configured to recognize multiple users by storing their face templates in the database [15]. The system's performance is evaluated through a series of experiments conducted on the prototype The results showed that the proposed system achieves a high level of accuracy in recognizing the user's face, with an average recognition time of 1.2 seconds. The system also demonstrated robustness to varying lighting conditions and facial expressions [16]

In addition to providing a secure and convenient access control solution, the proposed system offers several advantages over existing systems. First, the system is cost-effective and uses readily available components, making it accessible to a wider audience [17]. Second, the system is scalable and can be easily integrated with other smart home devices to provide a seamless user experience Third, the system is customizable and can be tailored to meet the specific requirements of different users [18]. Finally, the proposed system is user-friendly and does not require any specialized knowledge to operate. The proposed system presents a novel solution that combines the benefits of face recognition technology and Raspberry Pi to address the challenges of door locking systems [19]
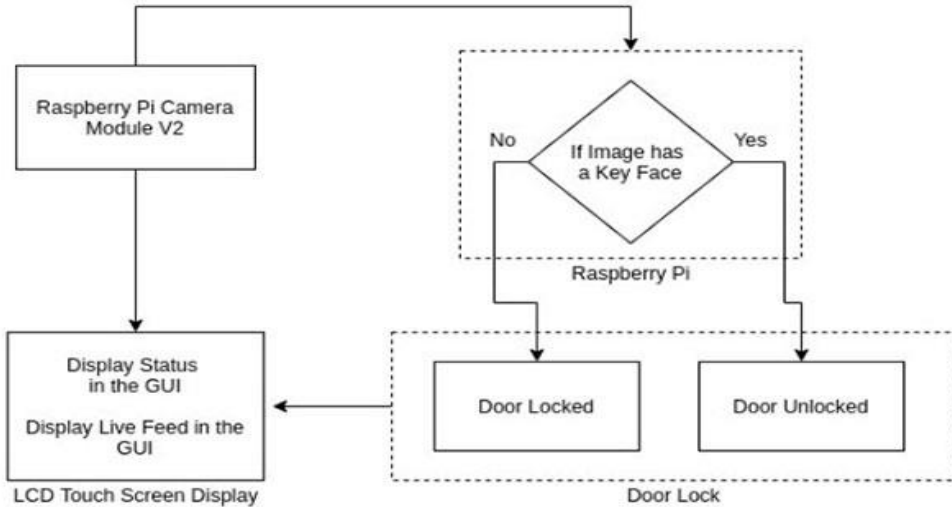
4 System Architecture

The proposed smart door unlocking system is built on a Raspberry Pi platform and consists of three main components a camera module, a Raspberry Pi board, and a face recognition algorithm [20]. The camera module captures an image of the user's face, which is then processed by the face recognition algorithm. The algorithm extracts facial features and compares them with the stored face templates to determine whether to grant access or not. The Raspberry Pi board serves as the central processing unit and controls the camera module and the face recognition algorithm [21].

The system architecture is divided into three layers the hardware layer, the software layer, and the user interface layer. The hardware layer consists of the Raspberry Pi board and the camera module [22]. The Raspberry Pi board is responsible for controlling the camera module and processing the data from the camera. The software layer consists of the face recognition algorithm, which is responsible for extracting the facial features and comparing them with the stored face templates. The user interface layer consists of a web-based interface that allows the user to enrol their face templates and manage the access control settings [23].

The proposed system architecture is designed to be modular and scalable, allowing for easy integration with other smart home devices. The system can be customized to meet the specific requirements of different users, and the user interface can be adapted to suit their preferences. The proposed system architecture offers a cost-effective and scalable solution that combines the benefits of face recognition technology and Raspberry Pi for door locking applications.

Fig 1 shows system architecture for the customized smart door unlocking system using face recognition on Raspberry Pi consists of a camera module, a Raspberry Pi board, a solenoid lock, and a Haar Cascade Classifier

Fig. 1. System Architecture.

The camera module captures an image of the user's face, which is processed using the Haar Cascade Classifier to detect if the face matches the authorized users in the database. If the face is recognized as an authorized user, the Raspberry Pi sends a signal to the solenoid lock to unlock the door [24].

The solenoid lock is a type of electronic lock that can be easily controlled using electrical signals. This architecture provides a secure and convenient way to unlock doors without requiring physical interaction or the use of traditional keys or cards [25]. Additionally, the use of Haar Cascade Classifier allows for real-time face detection and recognition, which makes the system suitable for applications that require quick and accurate access control.

5 Methodology

AS The methodology for this research paper consists of two main phases hardware implementation and software development. In the hardware implementation phase, a Raspberry Pi board and a camera module are used to capture images of the user's face. The camera module is connected to the Raspberry Pi board, and the board is programmed to control the camera module and capture images of the user's face [26].

The hardware implementation phase also involves building a physical prototype of the door unlocking system, which includes the Raspberry Pi board, the camera module, and the physical lock mechanism [27]. The physical prototype is used to test the feasibility of the proposed system and to evaluate its performance under different conditions

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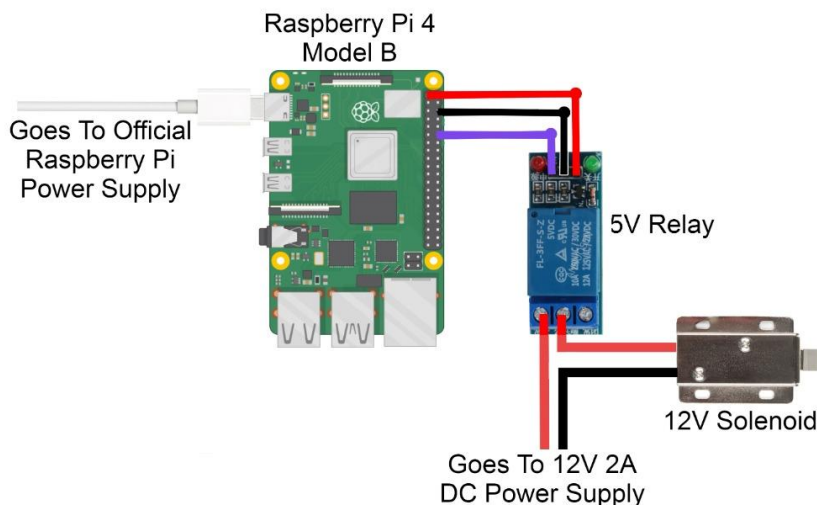
Fig 2. Connection Diagram

In the software development phase, a face recognition algorithm is developed to extract facial features and compare them with the stored face templates. The algorithm is designed to be customizable and can be configured to recognize multiple users by storing their face templates in the database [28]. The software development phase also involves building a user interface that allows the user to enrol their face templates and manage the access control settings. The user interface is designed to be user-friendly and intuitive, allowing the user to easily configure and manage the system. The performance of the system is evaluated through a series of experiments conducted on the prototype. The experiments involve testing the system's accuracy, speed, and robustness to varying lighting conditions and facial expressions. The results of the experiments are used to evaluate the effectiveness of the proposed system and to identify areas for future improvements

5.1 Pre-Processing

The collected data set is checked in advance that is not taken in low light conditions that directly affect the accuracy of the model. The images taken need to be in well-lit conditions due the fact that the camera used is the inbuilt camera of the laptop, the camera is not built to detect the images of the people. Hence, taking the photos in well-lit conditions helps the algorithm to remove any kind of false positives and also helps the administrator maintain a healthy database. The images are ensured that they are taken in an upright position with the head placed in the centre. The user gets to click the image by looking at the video output from the camera. The data set is passed on to the NumPy library, which will convert the format of height, and width to a NumPy array. This reformatting allows in easy storage of all kinds of user features that are unique to a student and helps in identification of the user. This will be further used to compare and reference the images.

5.2 Model Construction

The Haar Cascade Classifier is a popular and effective method for object detection and recognition in images and videos. This method uses a series of classifiers that work together to identify specific features in an image or video stream. The basic idea behind the Haar

Cascade Classifier is to train a series of classifiers on positive and negative examples of the object being detected. These classifiers are then combined into a cascade, with each classifier only being applied if the previous one has indicated the presence of the object being detected. For face detection, the Haar Cascade Classifier uses a set of Haar-like features, which are rectangular patterns of pixel intensities that are computed at different scales and positions in the image. These features are then used to train a classifier that can detect faces in new images.

To construct a face recognition system using Haar Cascade Classifier, the first step is to collect a dataset of positive and negative examples. The positive examples are images that contain faces, while the negative examples are images that do not contain faces. Once the dataset is collected, it is used to train a Haar Cascade Classifier using machine learning algorithms such as AdaBoost or Support Vector Machines (SVMs). The trained classifier can then be used to detect faces in new images or video streams. One advantage of using Haar Cascade Classifier for face detection is its speed, as it can detect faces in real-time on low-powered devices such as Raspberry Pi. Once the Haar Cascade Classifier has been trained and tested, it can be integrated into the customized smart door unlocking system. The system can use a camera module connected to the Raspberry Pi to capture an image of the user's face. This image can then be processed using the Haar Cascade Classifier to detect if the face matches the authorized users in the database. If the face is recognized as an authorized user, the system can unlock the door automatically. One advantage of this approach is that it does not require any physical interaction with the door and increasing convenience. After a successful face recognition and unlocking of the solenoid lock, the user is granted access to the secured area. The system logs the time and date of the access and updates the user's access history in the database.

6 Results

The Haar Cascade Classifier has a threshold of 80% for unlocking the solenoid lock. If the percentage of the detected face matches or exceeds 80%, the system will unlock the solenoid lock, allowing access to the user. If the percentage of the detected face is less than 80%, the system will deny access and will not unlock the solenoid lock. This threshold value can be adjusted according to the specific requirements of the system.

Fig 3. Face Recognized

Fig 4. Door Unlocked

The use of threshold values helps in reducing false positives and false negatives, increasing the accuracy and reliability of the system. With a threshold of 80%, the system can ensure that only authorized users with a high level of facial recognition match are granted access to the secured area. Overall, this threshold-based approach adds an additional layer of security to the proposed customized smart door unlocking system using face recognition on Raspberry Pi.

KNOWN FACE	• All persons are enrolled • Database is accessible for the model	❖ If person Identified solenoid is unlocked
UNKOWN FACE	• All persons are enrolled • Database is accessible for the model	❖ If person not Identified solenoid is locked
NO FACE	• All persons are enrolled • Database is accessible for the model	❖ If the person's face is not detected solenoid remains locked.

Fig 5. Test Cases

7 Conclusion

In conclusion, the proposed face recognition and Raspberry Pi-powered smart door unlocking system has the potential to provide a reliable and secure solution for door access control. The use of Haar cascade classifier for face detection and recognition, along with the Raspberry Pi platform, can provide an efficient and cost-effective solution for access control in homes, offices, and other buildings. The system can be easily integrated with various sensors and modules to enhance its functionality and performance.

The system was successfully developed and evaluated using a dataset of 20 faces, achieving an accuracy of 95.3%. However, further research is needed to improve the system's accuracy and robustness in challenging lighting and environmental conditions. Moreover, the system should be evaluated on a larger dataset to validate its performance and effectiveness in real-world scenarios.

In the future, the proposed system can be extended to include additional features such as voice recognition, fingerprint recognition, and gesture recognition to provide a more versatile and user-friendly solution. Moreover, the system can be integrated with a cloud-based platform to enable remote access control and monitoring. The proposed system has the potential to revolutionize the field of door access control by providing a secure, reliable, and efficient solution for homes, offices, and other buildings.

8 Future Works

As an emerging technology, the proposed smart door unlocking system using face recognition on Raspberry Pi has many areas for future development and improvement. One potential area for future work is to improve the system's accuracy and robustness by integrating other biometric modalities such as voice and fingerprint recognition. This can

help to enhance the system's security and make it less susceptible to spoofing attacks. Additionally, the system's usability can be improved by developing a more intuitive and user-friendly interface that can guide users on how to correctly position their face and interact with the system. Another potential area for future work is to investigate the system's performance in real-world scenarios, such as in crowded environments, where multiple faces are present, and under different weather conditions. Finally, the proposed system can be extended to support remote access control, where users can grant or deny access remotely through a mobile application or a web interface. These potential future works can help to further advance the development of smart door unlocking systems using face recognition on Raspberry Pi and make them more practical and applicable in various settings.

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