Design and validation of CAMERA INTEGRATION FOR IOT AUTHENTICATION

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ABSTRACT

Nowadays, people are quite worried about being able to keep their personal information safe from prying eyes, especially in places where theft, data breaches, or physical danger might occur. Because of their ease of theft, duplication, or loss, traditional security measures like keys, swipe cards, or passwords are becoming more and more perceived as insecure. This project presents a smart authentication system that utilizes face recognition for secure access management, which is based on the Internet of Things (IoT), to overcome these restrictions. A Raspberry Pi serves as the system's core processing unit and is constructed around it. An SD card stores the captured face photos in real-time, a Pi Camera operates an electronic lock, and an LCD display gives you visible feedback right away. The system checks the taken picture against a database of stored faces using the Open CV package in Python. If the faces match, the door is unlocked via the relay; otherwise, the owner is notified and the picture is saved for future reference. Displayed on the LCD are messages like "Access Granted" or "Access Denied" to enhance user communication. Additionally, the system records every attempt at access to the SD card. By doing away with the need for actual keys or PINs, this method lessens the likelihood of human mistake and security breaches. In addition to being small, affordable, and versatile, it may be used in a variety of settings, such as homes, workplaces, laboratories, and restricted areas. Additional biometric techniques, online storage, and connectivity with mobile apps are all possibilities for future improvements. An intelligent, automated, and dependable answer to today's security problems is what the project is all about.

Keywords: raspberry pi, pi camera, SD Card, Electric lock, relay device.

I. Introduction:

In today's world, ensuring secure access to homes, offices, and other restricted areas is becoming increasingly important due to the rise in thefts, unauthorized access, and security breaches. Traditional security systems such as physical locks, keys, and password-based mechanisms are no longer sufficient in providing reliable and tamper-proof protection. Keys can be lost or duplicated, and password becomes inaccessible or overlooked. In light of this, there is a rising need for automated security systems that are more intelligent, sophisticated, and easy to use. Using a Raspberry Pi and a Pi Camera [1] for face recognition, this project presents an Internet of Things (IoT) smart authentication system. The objective is to provide a contemporary and safe way to regulate access by using distinctive and hard-to-replicate face traits to identify people. The Raspberry Pi acts as the central

controller and is programmed using Python and OpenCV libraries to detect and recognize faces in real-time. When a person stands in front of the camera, their face is captured and matched against a database of authorized users. If the match is successful, a relay circuit is activated to unlock the electric door lock, and a confirmation message is displayed on an LCD screen.The system also captures and stores images of unauthorized users and sends notifications to the owner, enhancing security through remote monitoring. The entire setup is compact, cost-effective, and energy-efficient, making it suitable for deployment in homes, small offices, laboratories, and other controlled environments. Additionally, [2] the system logs all access attempts on an SD card for future review. By integrating hardware and software components with IoT capabilities, this project demonstrates a practical and reliable approach to modern-day security challenges, reducing the dependency on conventional access methods and providing a smart, biometric-based solution.

To design a smart and secure authentication system using Raspberry Pi and facial recognition.To capture real-time facial images using a Pi Camera for identification and access control. To compare captured images with a pre-stored database using Open CV for accurate verification. To control an electric lock using a relay module based on authentication results. To display real-time system status (e.g., access granted/denied) on an LCD screen. To store captured images and access logs on an SD card for future reference. To send alert notifications to a registered mobile number when unauthorized access is attempted.To create a cost-effective and reliable solution suitable for smart homes and restricted environments.

Problem Statement:

Traditional security systems rely heavily on physical keys, PIN codes, or swipe cards, all of which are prone to theft, loss, duplication, or unauthorized access. These outdated methods offer limited flexibility and often lack intelligent features such as real-time monitoring, user authentication, and remote control. In many cases, there is no way to verify who accessed a facility or when, which leads to significant vulnerabilities in both residential and commercial settings. Manual systems also require human intervention and are not scalable or efficient for large-scale deployments. Moreover, the absence of integrated alert mechanisms or identity verification poses serious threats to secure environments. The lack of automation and biometric verification creates loopholes in existing security measures. Therefore, there is a critical need for a smart, automated, and reliable security solution [3] that can minimize human involvement, authenticate users using unique biometric features such as facial recognition, and offer real-time access control through IoT integration.

II. Literature Review:

There has been a lot of buzz about the possibility of improving automation and security by integrating face recognition technology with embedded devices like Raspberry Pi. Several studies have shown that Raspberry Pi is a great, versatile platform for biometric access control systems since it is both affordable and easy to use. To demonstrate how effective feature extraction is in face analysis, Tudor Barbu presented a face recognition method based on Gabor filters. Similarly, a powerful real-time face

identification method was created by Paul Viola and Michael J. Jones; it is used extensively in image processing applications today. Several experimental projects have shown workable implementations of smart security systems utilizing OpenCV and Python. One such project is Tony DiCola's Raspberry Pi Face Recognition Treasure Box. [4] The simplicity of connecting Raspberry Pi to camera modules and relays was highlighted by Gopal Krishnan and Sathish Kumar in their demonstration of an image capturing system for surveillance in another research. Digital conversion procedures have been investigated by researchers such as Anoop Mishra utilizing Raspberry Pi, with an emphasis on comparing models and maximizing interface efficiency. A scalable and user-friendly option for constructing intelligent security systems may be found in the combination of Raspberry Pi with image processing libraries like OpenCV, according to the literature. The groundwork for future advancements in smart authentication systems based on the Internet of Things is laid out by these works.

III. System Architecture and Components

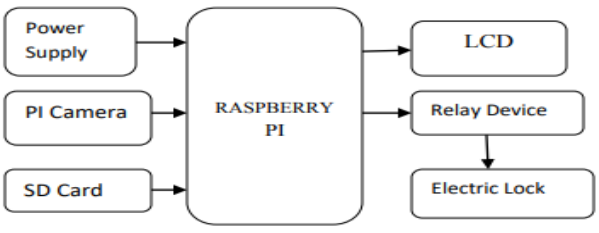

Fig1. System Block Diagram

Hardware Components:

1. The Raspberry Pi: A single board houses this tiny computer. Connecting a display, keyboard, and mouse to your Raspberry Pi turns it into a little computer. Raspberry Pi has several popular applications, including robotics, the Internet of Things, and real-time image and video processing. A little device known as a Raspberry Pi may provide all the required features and capabilities with minimal power consumption, while being slower than a desktop computer or laptop. Officially, the Raspbian OS—based on Debian—is offered by the Raspberry Pi Foundation. Additionally, they provide the NOOBS OS that the Raspberry Pi may run. A number of third-party operating systems are available for installation, including Windows 10 IoT Core, Ubuntu, Archlinux, and RISC OS. The official operating system, Raspbian OS, is freely available for your usage. On a Raspberry Pi, this operating system allows you to accomplish a great deal. With Raspbian's graphical user interface (GUI), you may access a wide range of programs, such as office, [5] gaming, Python programming, online surfing, and more. It is necessary to use an SD card with a minimum capacity of 8 GB to store the operating system data. A Raspberry Pi is more than just a computer; it's a platform that lets developers access on-chip hardware like GPIO devices. Through general-purpose input/output (GPIO), a vast array of devices, such as motors, sensors, LEDs, and many more, may be linked and managed. The Broadcom Processor SoC, which is based on the ARM architecture, and the graphics processing unit (GPU) are both housed within. The CPU speed of a Raspberry Pi may range from 700 MHz all the way up to 1.2 GHz. Also, you may install SDRAM with capacities from 256 MB all the way up to 1 GB. In addition to SPI, I2C, and I2S, the Raspberry Pi also comes with UART modules

already installed. Here is a list of all the various versions of Raspberry Pi:

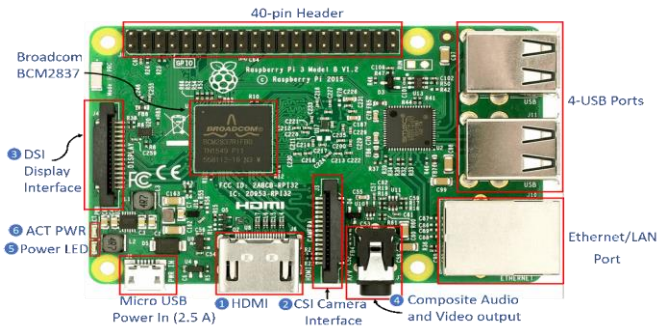

Fig2.Raspberry Pi

1. Relay:

A relay, a kind of switch, is powered by electricity. Relays are a kind of double-throw switch due to the fact that they have two switch positions. An electrical current flowing through a relay's coil attracts a lever, [6] which changes the switch's contacts. With the use of relays, a single circuit may control a whole other circuit. It is possible, for instance, to use a relay to switch a 230v ac mains circuit with a low voltage battery circuit. The relay connects the two circuits within mechanically and magnetically rather than electrically.

Fig 3. Relay

3. SD Card:

The SD Card Association (SDA) created the Secure Digital (SD) non-volatile memory card format for usage in portable electronics.SanDisk, Panasonic (Matsushita Electric), and Toshiba collaborated to establish the standard in August 1999 as an upgrade from Multimedia Cards (MMC). Since then, it has become the industry standard. Together, the three businesses established SD-3C, LLC, a business that licenses and protects the intellectual property rights related to SD memory cards, SD hosts, and related goods. In order to develop and promote SD Card standards, the firms jointly established the non-profit SD Association (SDA) in January 2000. Approximately 1,000 firms are members of SDA today. The SD-3C owns and licenses a number of trademarked marks that the SDA uses to ensure compatibility and enforce adherence to its requirements.

4. I2C LCD Display:

The acronym for liquid crystal display is LCD. Hobbyists and do-it-yourself electrical circuit/project creators are the ones who use character and graphical LCDs the most. It is simple to link them with a variety of microcontrollers since their serial and parallel pins are specified. We encounter LCDs in a lot of the goods we use on a daily basis. They serve as an interface for entering data or choosing a procedure, or[7] they display the product's state. Products with graphical or character LCDs installed include air conditioners, washing machines, microwaves, and mat cleaners. I'll be talking about character LCDs in this lesson. How do they operate? Their startup instructions, pin out, etc. There are several sizes of character LCDs, including 8x1, 8x2, 10x2, 16x1, 16x2, 16x4, 20x2, 20x4, 24x2, 30x2, 32x2, 40x2, and so on. Numerous international corporations, like Hitachi, Panasonic, and Philips, manufacture their own unique character LCDs for use in their devices. The functions of all character LCDs are the same: they show characters, numerals,

special characters, asci characters, and so on.They all have the same 14 pins (0–13) or 16 pins (0–15), and they all have the same programming.

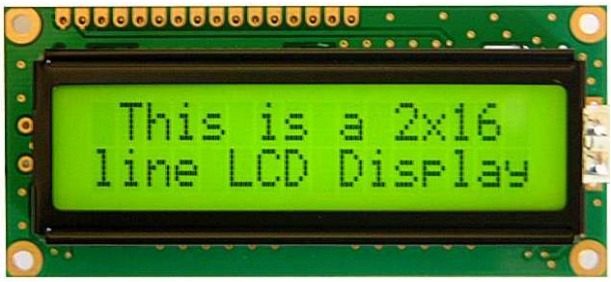

Fig 4. I2C LCD Display

The software and programming aspect of this project is primarily handled through the Raspbian OS installed on the Raspberry Pi. Python, a versatile and widely-used programming language, is used to develop the main control script due to its compatibility with hardware components and support for various libraries. The OpenCV library [8] is utilized for image processing and facial recognition tasks, enabling the system to detect and compare faces in real time. The RPi.GPIO library is employed to interface and control external components such as the relay module, electric lock, and LCD display. The authentication logic is written in [9] Python to analyze the input image and determine access by comparing it against a set of stored images. Data storage, including logs and captured images, is handled by saving them to the SD card. The LCD is programmed [10] using compatible Python libraries to provide real-time feedback. Together, this software stack enables a smooth, automated, and secure authentication process.

IV.Working Principle

The Raspberry Pi serves as the brains of the Internet of Things (IoT) [11-13] authentication system that incorporates cameras. The Pi Camera takes a live photo of whomever is at the door as they approach. Processing of this picture follows, with the help of the OpenCV library that the Raspberry Pi has loaded. The system checks its database for previously saved photos to see whether they match the one being recorded. If the faces are a good fit, the Raspberry Pi will trigger the electric lock to open the door by sending a signal to the relay module. At the same time as the entrance is confirmed, an LCD[14] display presents a message like "Access Granted" to let you know.

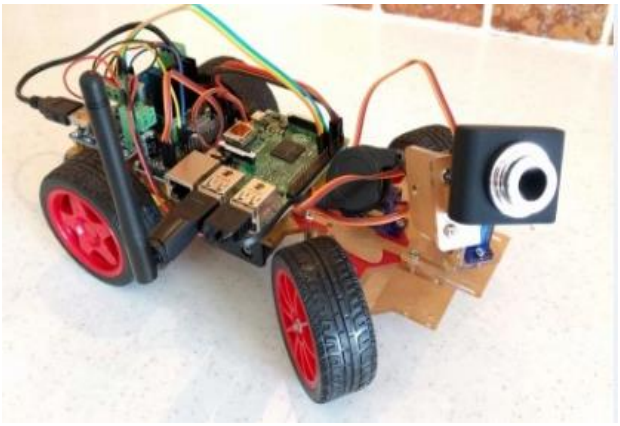

Fig .5.circuit level of Iot Authentication With Camera Integration

If the system does not recognize the face, access is denied, and the LCD displays “Access Denied.” Additionally, the camera captures the intruder’s image and sends an alert message with the image to the registered mobile number or email, depending on the configuration. All captured images and logs are stored on the SD card connected to the Raspberry Pi [15] for future reference. The system is powered by a regulated power supply to ensure smooth operation of all components. This setup provides a contactless,

automated, and secure authentication method suitable for smart homes and restricted areas.

V. RESULTS

The implemented Raspberry Pi-based authentication system successfully achieved its objective of providing secure, automated access control using facial recognition. The Pi Camera accurately captured real-time facial images, which were processed using Python and the OpenCV library. Upon successful recognition, the relay module triggered the electric lock to grant access, while the LCD provided instant feedback. In case of unrecognized faces, the system captured the image and sent an alert to the registered mobile number. All operations, including data logging and image capture, functioned reliably. The system proved to be efficient, cost-effective, and suitable for modern smart security applications.

VI. FUTURE ENHANCEMENTS

The proposed IoT-based facial recognition system offers great potential for future enhancements to improve its functionality, scalability, and security. One of the most promising upgrades is the integration of advanced machine learning algorithms to enhance facial recognition accuracy under different lighting conditions and angles. Cloud storage can be added to enable remote data access, backup, and centralized monitoring from multiple locations. A mobile application can be developed to provide real-time notifications, access logs, and remote unlocking capabilities. Additional biometric authentication methods such as fingerprint, retina, or voice recognition can be incorporated to provide multi-factor authentication for higher security levels. AI-based features like emotion detection or behavior analysis may also be explored. Solar power integration can help in achieving energy-efficient and eco-friendly operation, especially in remote areas. The system can be extended to smart cities and enterprise security infrastructures, making it a comprehensive and intelligent access control solution for the future.

VII. CONCLUSION:

The implementation of an IoT-based authentication system using Raspberry Pi and facial recognition technology presents a modern, efficient, and reliable solution for enhancing access control and security. By integrating components such as a Pi Camera, SD card, relay module, electric lock, and LCD display, the system offers an automated method for identifying individuals and granting or denying access accordingly. The use of facial recognition removes the potential security risk associated with physical keys or passwords, making it far easier to prevent illegal access or human manipulation. Supporting real-time image processing and other tasks, the Raspberry Pi is an affordable and versatile platform.control operations. The system ensures data logging, visual feedback, and mobile alerts, enhancing both usability and safety. Its scalability and compact design make it ideal for homes, offices, laboratories, and restricted environments. This project demonstrates the effectiveness of embedded systems and IoT integration in security applications and opens the door for future upgrades such as cloud connectivity and multi-modal biometrics.

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