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Development of Face Recognition Smart Door Lock System Using ESP32-CAM and Telegram Application As Media Control and Monitoring

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Abstract: Face Recognition Smart Door Lock System Using ESP32-CAM and Telegram Application as media control and monitoring is a system specially designed for smart door lock system at home to make daily human tasks more accessible and streamlined significantly and to analyze the performance of a security door system that uses the IoT to notify users if a stranger wants to break into a home or visit the house. Nowadays, facial recognition is a well-established and popular process to ensure a safer home. Here, facial recognition helps to detect and recognize faces automatically or with control to allow entry into the home. The system is designed to make it easy for residents of Kolej Kediaman Pagoh to enter their homes and help students to control and monitor the smart door lock to increase the security system. The object-oriented approach is used to develop the system using various IoT devices such as an ESP32-CAM that acts as a microcontroller that carries input and output to switch on/off the magnetic lock, an Infrared Sensor Module, Telegram Application, 5V Single Channel Relay Module, and KPEG-353 Piezo Buzzer. The appliances can be controlled and monitored easily through the Internet or Wi-Fi, linked to the smartphone's Telegram Application. The System Development Life Cycle (SDLC) methodology was used to complete the project. This system makes it easier for residents to enter the house and protect it from intrusion and burglary. We will be able to make the home safer with a user and economy-friendly system. For a future project, improvement can be made by adding a directional antenna to increase the Wi-Fi range.

Keywords: Smart Door Lock, Internet of Things (IoT), ESP32-CAM, Telegram, Face Recognition

1. Introduction

Physiological features include the body's shape, such as palm veins, retina, iris recognition, facial recognition, and palm print. Behavioral characteristics are related to the pattern of behavior of an

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individual, such as gait, voice, and typing rhythm. In computer science, it is used as a means of verifying personal identity and access control. Security Deft has recommended several strategies to increase security, including biometrics and passwords. Face recognition has become a popular authentication and security system technique. It is a digital image processing method that uses a person's image as input to identify someone. Face recognition is crucial since a person's face works as their primary form of identification and because faces range significantly in shape, making it simple to recognize someone by their appearance [1]. Each approach mentioned has advantages and disadvantages, such as the value of device compatibility.

Keyless locks can help students feel safer in their homes by reducing their criminal exposure at the University. A keyless lock can also help students save money without paying negligence fines. The primary purpose of this project is to facilitate human affairs and improve security in the hostel, especially for the door lock system. The idea was to develop a facial recognition system as a home access control by capturing faces. The system will be developed using ESP32-CAM, and IoT - a based door lock will be used.

A home is a place that can create comfort, security, and tranquillity. The same goes for dorms in residential colleges. The major concept of this technology is to make resident life easier and to improve the performance of the smart door lock in the market. The door lock system using facial recognition and Telegram notifications is an IoT system that also can prevent someone not authorized from entering the house because it requires facial verification to open the door [1]. Face recognition, as we all know, is a pattern recognition technique that uses faces as input to improve the security system [2]. This system also helps people open doors easily and quickly, especially in the era of Covid-19 or other viruses. This technology's primary goals are to systemize residents' life and enhance the market performance of smart door locks. The ESP32-CAM captures face images, which are then recorded in a database. If the image matches that of the administration, the door will unlock, and a confirmation will be stored in the database system; otherwise, the solenoid will turn off, or the door will not open if the face does not match what has been registered or someone else's face. The device will notify the owner on the Telegram App if an intruder tries to break into the house by capturing and sending his photo and activating the security alarm. The user can unlock the door or turn on the buzzer with the help of a mobile phone as soon as they get a notification [3]. This system also can be for the guest system. Here, everything system operates according to the developed code (mostly C# and Python).

2. Materials and Methods

This chapter will provide a detailed overview of the materials and methods used to finish and test this project.

2.1 Literature

The approach meets the project's goal of providing a perfect result. The technique used to evaluate this project is based on the System Development Life Cycle (SDLC), which has three primary steps: planning, implementation, and analysis.

Based on the articles, all the products used cameras and wireless communication technology to execute the command, which is convenient for the user. Face recognition is a pattern recognition technique that uses faces as input to strengthen the security system [4]. The second article discussed the developed system that can integrate IoT networks and cloud computing, making this system very user-friendly and versatile even though it does not require high costs. It could benefit the product because it can be used for long-distance remote control even if the user travels in another country. On the other hand, the

disadvantage is the limited notifications, and warning systems make the product low-security, although it was easy to operate and install.

A face recognition-based door unlocking system using Raspberry Pi is the product built in the third article. A better security system is the advantage of the product because the two-step verification was developed. The method uses the LBPH (Local Binary Pattern Histogram) Algorithm. This algorithm will give the product more accurate results than other algorithms in the base paper, such as Fisher Face and Eigen Faces Algorithms [5]. It has created a highly secure door-locking system using Raspberry Pi. The disadvantage was found to be the cause of complex installation and lower bandwidth. The fourth article comes with the title Automatic Door Lock System by Face Recognition[6]. The system also recognizes faces by using cascade classifiers, which get high accuracy and will store in the database. From the title, we can observe that if a person is detected, the door opens and welcomes them, but if an unknown person enters, the owner would be alerted by message and mail with an intruder image. Because of the system's accuracy, the complex setup of the product was their disadvantage. It will take time to complete the effect. Because of Bluetooth communication makes the product's function range and data rate lower than Wi-Fi or internet communication.

Furthermore, the fifth article illustrated A GSM. By using Global System for Mobile Communication (GSM) control, which provides a high-security system because only the desired phone can send the control message or receive feedback from the GSM modem [7]. Cost is the disadvantage of it. GSM communication requires Short Message Service (SMS) and a GSM modem to send and receive data. Therefore, the user must purchase a modem and get charged for every SMS command. The last article is about the Smart Door Security System using Raspberry Pi with Telegram, a social system[8]. The product was very high security because Network security plays a Vital role; the PUTTY and PUTTY GEN are used for SSH (secure shell). The SSH key is generated using an asymmetric cipher, such as the generation of one public and private key. Also, Additional Fail2ban software. The public key can be shared among users, while a private key remains with the owner.

2.2 Material

The material for this project was chosen based on the requirements for the prototype that was designed. Table 2 shows the hardware used in the project with the item's name, pictures, and some explanations. All these components are manually assembled, with each of the connections being studied and observed so that the misconnection of the details will cause no error.

Table 2: List of Hardware

No	Items	Pictures	Explanations
1	Esp32 cam		The ESP32-CAM is an ESP32-based camera module with a small size and low power consumption. It has an inbuilt TF card slot and an OV2640 camera. Wireless video surveillance, Wi-Fi image upload, face identification, and other intelligent IoT applications can all benefit from the ESP32-CAM.
2	12V Solenoid lock		The Selenoid Door Lock is utilized as an actuator, allowing the door in this system to open automatically based on the condition of the relay. Theload relay terminal block is generally open and attached to the solenoid door lock.
3	Single Channel 5V Relay Module		A single-channel 5V relay module was an easy-to-use board for controlling high voltage and current loads. The relay module protects the system voltage, which acts as a circuit breaker.
4	UART TTL		A mini-B USB port on the module is utilized to connect to an

	Progra mmore		interfaced device's USB port (e.g., a PC). The breakout pins (Tx, Rx, Vc, and GND)on the FTDI USB to TTL serial converter module, on the other hand, areconnected to the corresponding pins on a microcontroller.
5	Buzzer Sensor Module		If the facial image taken matches or does not match an existing database with a different sound state, the buzzer will sound like an alarm.
6	Jumper Wires 40 - Female toMale		Jumper wires have connector pins on both ends that can connect two places without solder. Jumper wires are commonly used with breadboards and other prototyping tools to allow for quick circuit changes.
7	Breadb oard 60x50 mm		Before finishing any circuit design, a breadboard is used to develop and test circuits rapidly. Circuit components such as ICs and resistors can be put into the breadboard's numerous holes.
8	Mini USB Cable (30cm)for UART TTL Programmer		The USB cable for the UART TTL Programmer can be used to power and program the ESP32 Cam board. For the board, they're detachable.
10	IR Sensor		An infrared sensor is an electronic device that emits light to detect objects in the environment. An infrared detector can detect motion and measure an object's heat. In this investigation, an infrared sensor is employed in place of the bell button.
11	AC Converter Adapter DC 12V 400mA Switching power supply		The high voltage from a wall outlet is simply converted to the low voltage needed to power Relays by an AC Adapter. It reduces the 110V to 220V AC input voltage to produce 12V DC output voltage.

2.3 System Block Diagram

The general system block diagram is typically designed to help the project with ideation and design reference. This is essential to ensure the system's resilience in the future. From Figure 2.1, the system is built using EPS32 as the central controller of data traffic that occurs in the system. The power supply is connected to the microcontroller and relay. The IR sensor is also connected to the microcontroller as an auto-detect the presence of obstacles and sends the signal in waveform to the microcontroller. The IR sensor act as a doorbell and the camera module type OV2640 is used to detect and recognize the user's face, which will then be sent to the telegram application connected to an Internet connection. The system has a buzzer connected to a microcontroller that issues an alarm sound if the detected face an intruder. Wi-Fi microcontrollers allow devices to connect to the internet, send and receive data, and accept commands. The ESP32-CAM specification can operate for 2.4 GHz Wi-Fi, supporting WPA/WPA2.

Figure 2.1: Basic Block Diagram of Project

2.4 System Flowchart

This system detects faces and sends pictures to Telegram, as shown in Figure 2.2. The program will initialize all the sensors and hardware connected to the ESP32-CAM. For the first task for this system flowchart, the condition is whether there is an interruption on the OV2640 camera and IR sensor. If there are interruptions, system ESP-32 CAM will detect whether that face is entered correctly. The relay will help to unlock the solenoid door lock. This solenoid will be active for 5 seconds, after which it will close again automatically, and the door will be locked. Then, a Telegram notification will display on the smartphone. If that face is entered incorrectly, ESP32 will provide information through the Telegram application in images with buttons "/open,"/still,"/buzzer_ON," and "/buzzer_OFF." Its functions as a remote and monitor control.

Figure 2.2: System Flowchart

2.5 Software Development

In developing this prototype, ESP32-CAM is programmed using Arduino IDE. The program is structured to connect a defined Wi-Fi connection and connect it directly to the Telegram Application.

2.5.1 System with Telegram

In this project, Telegram is used to notify the homeowner about an unknown face at the door. It is in both text and image. Telegram is a free application that can be downloaded on various bases gadgets as long as the application is installed. Telegram Developer also provides an Application Programming Interface (API) programmed with multiple programming languages such as Python or, in this case, long method poll. The following describes how to create a view Telegram Bot as a display to users. For can be made via the telegram application on a smartphone or via the Telegram web, as well as how to connect Telegram with the Arduino IDE.

A command will appear to create a username for our bot, which must be accompanied by the word "bot." Then copy the code; a number is a code of our API tokens. This token will be the reference for later bots that can be programmed to send text, images, videos, and others, as shown in Figure 2.3.

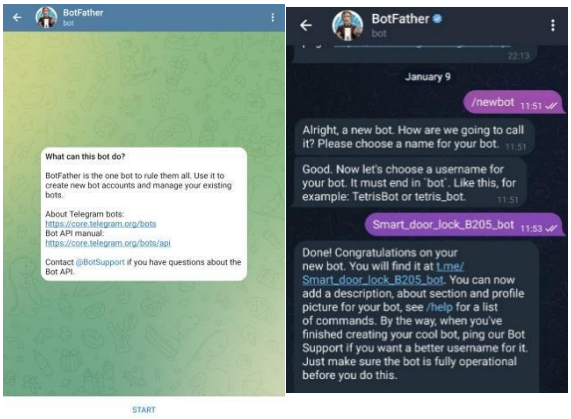

Figure 2.3: BotFather Display in the Telegram Application

2.5.2 The system with Arduino IDE

Development Environment (IDE), where the design uses a driver that must be installed first. Its aim at connecting the ESP32-CAM. Opening the file menu of the Arduino program work page as shown in Figure 2.4, then going to preferences and entering the web address in the reference so that the ESP32 board is installed in the Arduino IDE.

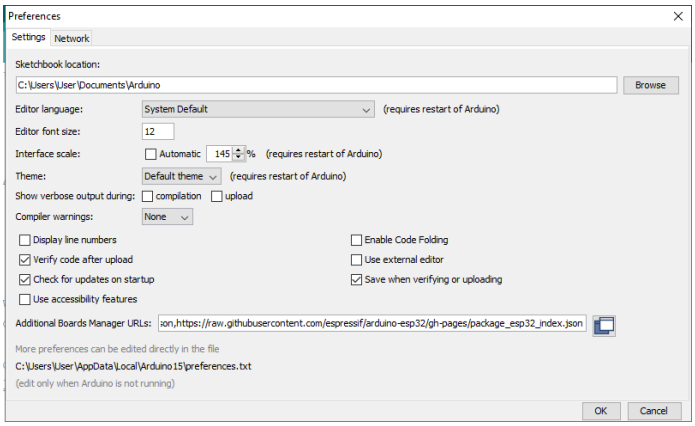

Figure 2.4 Arduino IDE Work Page

Figure 2.5 is the coding of Arduino to define the authentication code, SSID, and password. The core is the send text and image function. We need to insert our network credentials in the following variables. Then, make sure we select the suitable camera module. In this case, we're using the AI-THINKER Model.

```
const char* ssid = "Mira";
const char* password = "17venteen";

String myToken =
"5904048589:AAFQLUiOrrIOniYbOiv_4T3cfDARoxUy1my";

String myChatId = "123456789";
```

Figure 2.5 Authentication code, SSID, and password

3. Results and Discussion

In this chapter, several hardware and software development experiments are conducted to obtain the data for analyzing the product from different aspects such as connectivity esp32-CAM and Wi-Fi, ESP32-CAM Testing, Telegram Notification Testing, and Camera OV2640 sensor Testing. Functionality and accuracy testing is done to get the best results. Based on these experiments, a discussion will be made according to the result obtained from that experiment, and graphs will be plotted to observe the trend.

3.1 Hardware Development

The infrared sensor in this study is used as a substitute for the bell button. The relay utilizes the electromagnetic principle to move the switch contacts. With electric current small (low power), the relay can deliver higher voltage electricity. So that door lock solenoid is working, it needs help with relays and power supplies. The power supply provides 12V power to the relay and door lock solenoid. So, the voltage changes to 5V with the positive power supply pin connected to the NO relay, the negative power supply connected to the negative solenoid door lock, and the positive solenoid door lock attached to the COM relay. The relay connected with ESP32-CAM with a relay output pin to GPIO12, GND to GND, and VCC to VCC (5V).

There are two wires on the buzzer that connect to ESP32-CAM. The positive pin is connected to the GPIO15 pin, and the negative pin is connected to GND on the ESP32-CAM. Future technology devices international (FTDI) on the ESP32-CAM is designed so that when entering the source code of the Arduino IDE application, the ESP32-CAM module can be connected with good. FTDI can support devices for converting transmission to and from the universal signal serial bus (USB) with the computer. This connection shows in Figure 3.0.

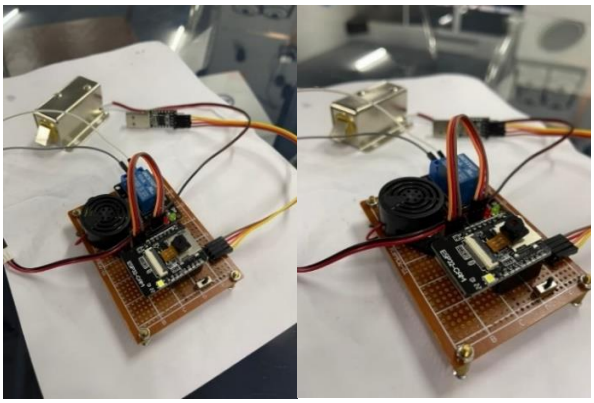

Figure 3.0: Hardware development and installation

Figure 3.1 represents the finalized prototype of the smart door lock system built using recyclable materials such as cardboard. The ESP32-CAM acts as the main prototyping module for this project. It works for direct access to open the door using facial recognition for resident access and a telegram notification that controls opening the room using a smartphone when the ESP32-CAM encounters a system error and guest access. It is also used to detect the presence of thieves. The various components used are connected to the ESP32-CAM board via multiple pins. The IR sensor acts a doorbell. The result of this hardware is implementing the smart door lock system dormitory room door.

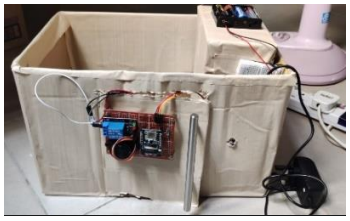

Figure 3.1: Front View of the product

3.2 Software Development

The implementation of the planned Internet of Things-based room door security system includes facial recognition by utilizing features on ESP32-CAM, notification display, and Telegram display and hardware website.

3.2.1 Face Recognition System Page

The display feature on the ESP32-CAM provides a web server for the identification system face. On this page, the system will be live to detect the face that was previously registered or otherwise, and there is a notification about the face shown. The page view can be shown in Figure 3.1.

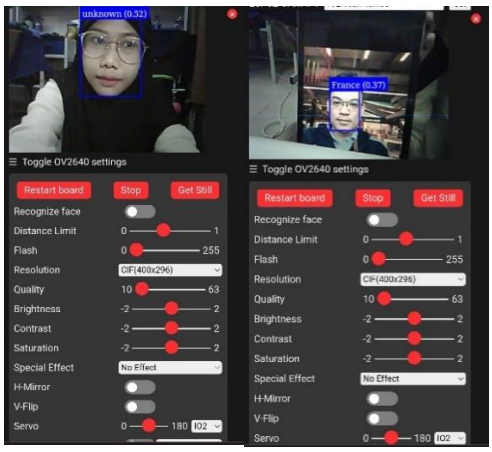

Figure 3.1: Display of Face Recognition System

3.2.2 Live Streaming page

An index page is a page that serves to display the main page on the created website. The main page on the website is made for the live streaming feature, as shown in Figure 3.2.

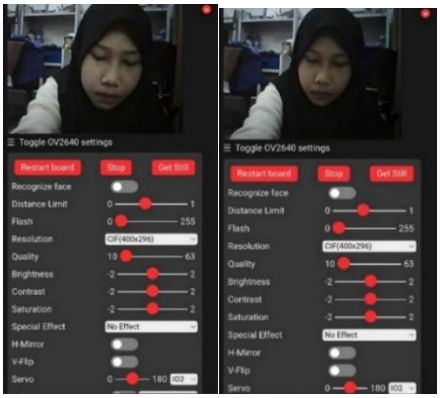

Figure 3.2: Live Streaming Display

3.2.3 Telegram Notification Display

Telegram notifications will appear when the system detects guests, thieves, or strangers and adds notifications when the door is opened. Photo command to instruct the ESP32-CAM to snap, and the photo will be sent via Telegram. There are four buttons that the system has implemented, as shown in Figure 3.3. The door lock solenoid will be opened if the "/open" button is pressed and the "/still" button is pressed if you want to take pictures front. The "/buzzerON" is pressed manually when the system detects a thief, and "/buzzerOFF" works to stop the buzzer.

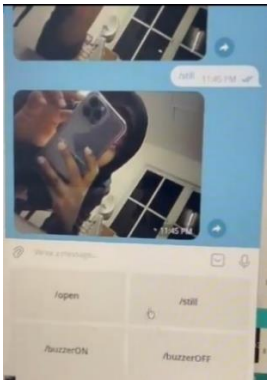

Figure 3.3: Telegram Notification Display

3.3 Result of product testing

This subchapter focused on the discussion of the obtained results and the project analysis. The main aspects of fulfilling this chapter are product testing and data analysis. Tables, graphs, pie charts, and bar charts are used to represent testing results.

3.3.1 Connectivity Between ESP 32-CAM and internet

A microcontroller known as the ESP32-CAM has Wi-Fi built into it, allowing it to connect to other devices online and communicate with them. In this experiment, a smartphone is a modem connecting the ESP32-CAM to the internet. By separating them over various distances, the connectivity between them is tested from the five experimental data. The ESP32-CAM and the smartphone were separated by 1,10,000 and 1,000 meters, as shown in Table 3.1. The results show that the system can be connected up to a distance of 100 meters and not connected at 1000 meters.

Table 3.1: Connectivity Between ESP32-CAM and WIFI

Distance (Meter, m)	Connectivity				
	1	2	3	4	5
1	Connected	Connected	Connected	Connected	Connected
10	Connected	Connected	Connected	Connected	Connected
100	Connected	Connected	Connected	Connected	Connected
1000	unconnected	unconnected	unconnected	unconnected	unconnected

According to the illustration in Figure 3.4, the maximum distance the ESP32-CAM could connect to the internet is 100 meters cause there is a limited distance between the ESP32-CAM and the smartphone WIFI. The WIFI standard is 802.11n, which supports up to 100 meters above. Moreover, other factors can affect connectivity, such as the structure of the building, the number of windows, obstacles, and the interference of other electronic devices. It can reduce the connectivity of the ESP32-CAM to the internet.

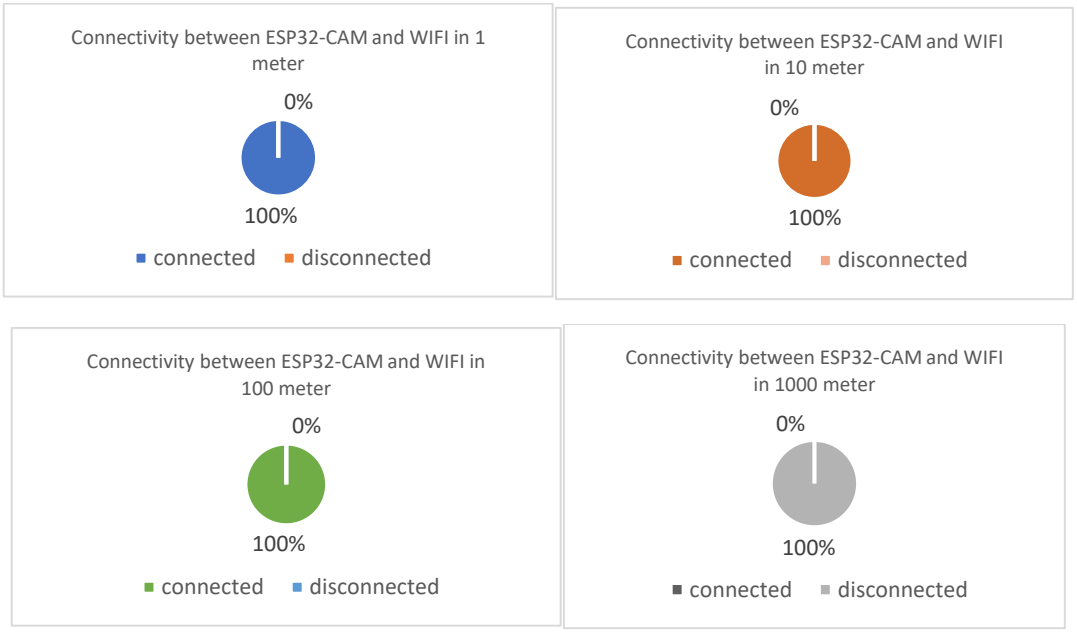

Figure 3.4: Connectivity Between ESP32-CAM and WIFI

3.3.2 ESP32-CAM Testing system.

The ESP32-CAM test is conducted in the procedure outlined below. Observe the ESP32-CAM's web server features and contrast the outcomes of two people's detection of six faces. Table 3.2 displays a testing system to unlock the solenoid door lock to open the door; 10 trials were conducted to demonstrate this approach's effectiveness.

Figure 3.5 shows the chart analysis from Table 3.2 results. There are two registered faces, and shows the faces in the database. There is a failure system with a face-mounted identification indicator. In experiments 1,2,3 and 4, the ESP32-CAM success in detecting and recognizing faces registered in the. It also successfully detect strangers in experiments 5 and 6. While stranger photos were utilized in experiments 7 and 8, and 9 to test the ESP32-CAM. Lastly, toys are used to test the detection in experiment 10, but the system cannot detect it.

Table 3.2: ESP32-CAM Testing system

Experiment with Face and Photo	Face detection	Face recognition	Door lock	Error	Accurate
1	yes	yes	unlocked	0%	100%
2	yes	yes	unlocked	0%	100%
3	yes	yes	unlocked	0%	100%
4	yes	yes	unlocked	0%	100%
5	yes	no	locked	0%	100%
6	yes	no	locked	0%	100%
7	no	no	locked	0%	100%
8	no	no	locked	0%	100%
9	no	no	locked	40%	60%
10	no	no	locked	100%	0%

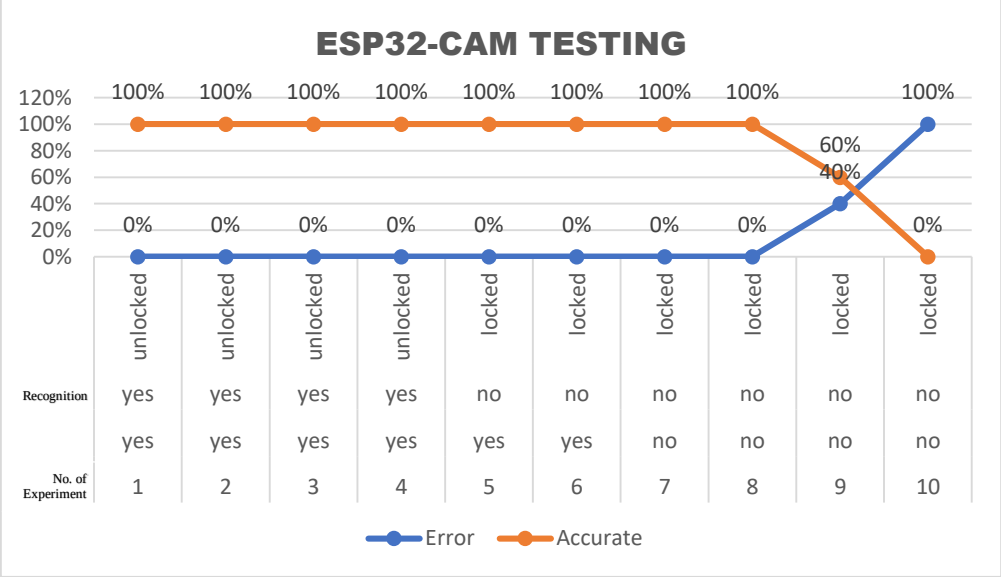

Figure 3.5: ESP32-CAM Testing System

3.3.3 Telegram Notification Testing

Telegram notification testing in this study shows the level of success and response time required by the system. Test telegram notification is shown in Table 3.3. Figure 3.6 illustrates the bar chart from the result of Table 3.3. Got it too known from Table 4.4 shows that the delay time required by the system detection until finally, the image and text data received by Telegram is the longest, with a delay of 4.92 seconds, and the fastest delay is 4.82 with an average delay of 4.87 seconds. It is because the system works the first time. The system will do the training, save the data to the library beforehand, and do the matching so that after the storage and matching process is complete, the system will send data to Telegram. Send data to Telegram will be affected by the internet speed on ESP32- CAM and the file size.

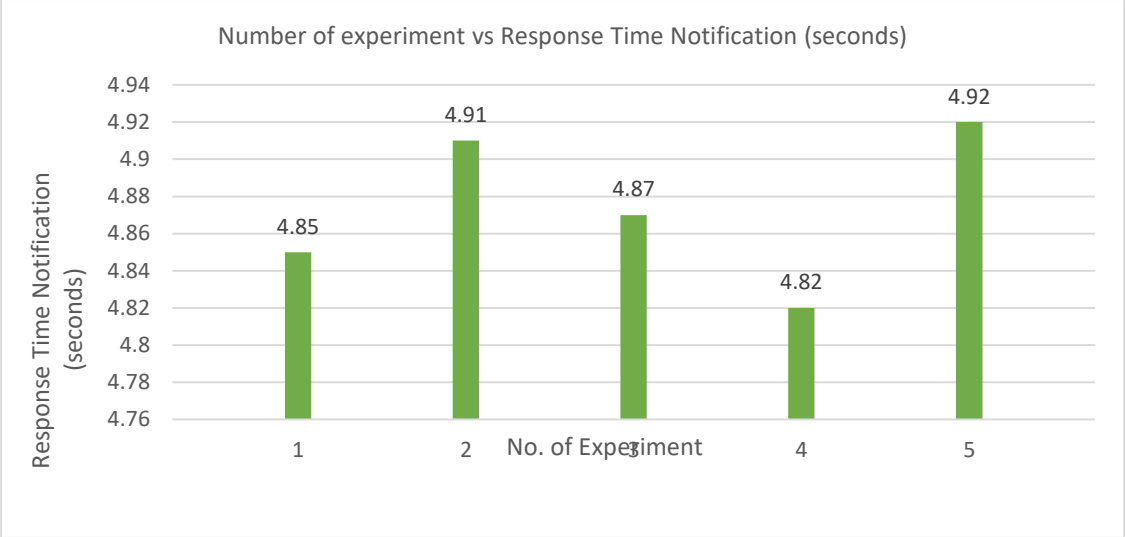

Figure 3.6: Telegram Notification Testing

Based on the test results in table 4.4 shown after five trials that the telegram notification has been successfully sent, there is a slight difference in response time at 4-5 seconds.

Table 3.3: Telegram Notification Testing

Number of experiment	Result	Response Time Notification (seconds)
1	Sent Successfully	4.85
2	Sent Successfully	4.91
3	Sent Successfully	4.87
4	Sent Successfully	4.82
5	Sent Successfully	4.92

3.3.4 Camera OV2640 sensor Testing

The camera OV2640 sensor is tested to identify the ratio of the distance produced by the sensor. Table 3.4 demonstrates that up to five tests can successfully detect the OV2640 Camera sensor, as illustrated in Figure 3.7. Because no difference was observed throughout the five tests when the sensor detected an object, the outcomes are encouraging. The microcontroller's ability to work with low-level standards makes it possible for the OV2640 camera to take and analyze images of things in the room. The module is compensated by a wire connected to the OV2640 camera sensor, which has a wide-angle lens and a 160-degree viewing angle. It allows the collection of images with a resolution of up to 1600x1200 and a maximum refresh rate of 15 FPS. The microcontroller's use of low-level protocols.

Table 3.4: Camera OV2640 sensor Testing

Experiment no.	Object(cm)	Result	Difference(cm)
1	10	Success	0
2	15	Success	0
3	20	Success	0
4	25	Success	0
5	30	Success	0

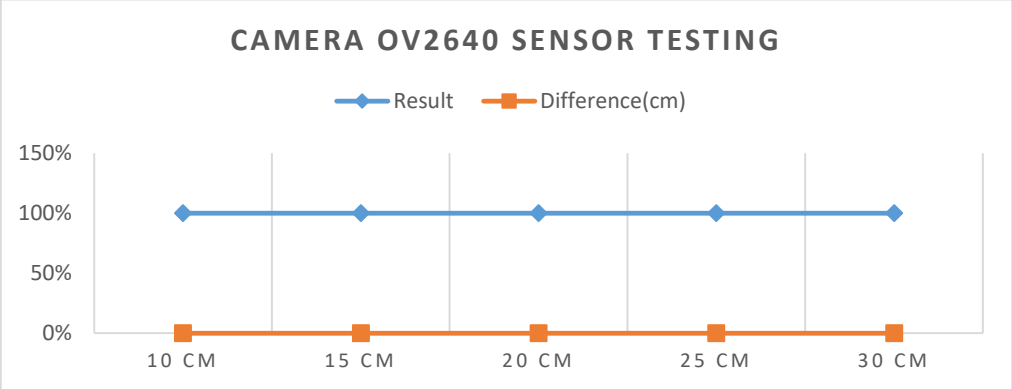

Figure 3.7: Camera OV2640 sensor Testing

4. Conclusion

This system will help users to control and reduce the waste of energy resources, especially with the daily workload. To build a smart door lock system by developing a program that can improve a portable, high-efficiency, low-cost, and easy-to-operate security system where it can prevent cases of home theft from occurring. Integrated inside its smart entry lock is a wide-angle camera. Whenever user entry has been unlocked, use facial recognition or check someone and let them in automatically using the high-resolution and wide-angle lens. To build a system that uses IoT to notify the user if a stranger wants to enter or visit the house. The ESP-32 CAM and the Telegram Application are the central hub of the project and provide communication between them. View event history and receive notifications about innovative lock behavior from the App. Passcodes and IC cards are no longer used in Privacy Lockout Mode. This technology protects public health and prevents germs from the air and direct human contact with the virus. Facial recognition technology is resistant to infectious pathogens, unlike biometric and touch-based security solutions. The cost of this facial recognition-based Smart Door Lock system is accessible for every home, especially considering economic factors. It is advised that researchers conduct further research using directional antennas to increase the Wi-Fi range of the ESP32 and develop better microcontrollers for future work. ESP32-CAM can upgrade to the latest version on the market or change to a new version of Rasberry Pi, which is more powerful and has more features and security. The code for the database can be improved to improve the system in the future.

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