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Home Door Security System with Face Recognition Using ESP 32 Cam

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Abstract—The development of science and technology, especially in the fields of Electronics and Informatics, is expected to enhance room or home security systems, particularly home door security systems. Many door security technologies have been developed to prevent and ensure the comfort of homeowners when they leave their homes. Some commonly used door security systems include CCTV cameras, fingerprint sensors, voice sensors, and RFID. However, with technological advancements, these security systems have shown vulnerabilities, such as frequent errors in fingerprint and voice sensors. Based on this, to create a more secure and innovative home door security system, the authors developed a security system with face detection and a remote warning notification system using Telegram. The researchers created a door security system using the ESP 32-CAM for face detection and as a controller for the Internet of Things (IoT) system. Additionally, a manual system using a keypad for password input was also created. The results of this study include the accuracy and speed of face recognition and the speed of sending security system warning information through the Telegram application.

Keywords— Door Lock System, Face Recognition, ESP32 Camera, Microcontroller, Internet of Things.

I. INTRODUCTION

In today's era, criminal acts cannot be separated from daily life because criminal actions can occur anytime and anywhere when the perpetrator has an opportunity, such as in the case of home burglary. This often happens by damaging or breaking the lock system on doors or windows, which are the main access points to a home. Even theft can occur while the homeowner is still inside the house. Although the door is locked, burglars can still unlock it using just a wire and a screwdriver. Due to the high rate of crime, especially theft, a home security system becomes an absolute necessity [1].

An automatic door security system is one of the results of the current development of science and technology. The use of conventional keys, which are still widely used by the public, is easily disabled by criminals. Additionally, the use of conventional keys in a security system is less reliable because the keys can be lost or misplaced, making this system less practical and vulnerable to theft [6]. Several modern security systems have been developed, such as using fingerprint sensors on door handles or voice-activated systems. These two security systems have their weaknesses. Fingerprint sensors are very sensitive to dust, damaged fingerprints, or incorrect fingerprints, while voice-based security systems can easily be sabotaged by people who can imitate other people's voices. This is often exploited by professional thieves.

So far, the conventional door lock system generally uses physical access control, such as the use of buttons and cards [9]. An automatic door lock system without physical access control allows for a simpler design, such as a door without a handle or keyhole. Therefore, an automatic door lock system using an innovative method to prevent theft, considering the current high crime rate, and to provide a solution for conventional door lock systems without using physical access control is needed. One of these methods is a face recognition system. A door security system using face recognition is a modern concept that does not require access control with physical devices [2]. It can also be controlled remotely, known as the Internet of Things. Based on the background of the problems discussed, this research aims to develop a door security system using face detection or face recognition based on the Internet of Things. The ESP32-CAM is used as a controller to recognize the homeowner's face. This can increase the homeowner's sense of security because unauthorized persons cannot enter the house due to the face recognition security system.

II. METHODS

Researchers have developed a home door security system with face recognition using the ESP32-CAM. The initial design of this device aims to reduce human intervention with a simple design and efficient performance. The automatic door lock opening system using the ESP32-CAM can prevent home theft due to the high crime rate and provides a solution for the door lock system. To better understand the overall design of this device, see the diagram below.

A. Product Design

The design starts from the stages of designing, material selection, manufacturing, and testing of the device to achieve optimal and measurable results, in accordance with the authors' goals in developing this device. The electrical circuit in the door security system uses two controllers: Arduino Uno and ESP32-CAM. The main power source for the Arduino controller is 5 volts, while the power source for the ESP32-CAM is provided by 5 volts from the Arduino Uno. Additionally, a 12-volt battery is used to power the solenoid door lock. The following is the overall electrical circuit design. Next, the microcontroller will process the data received from the sensor.

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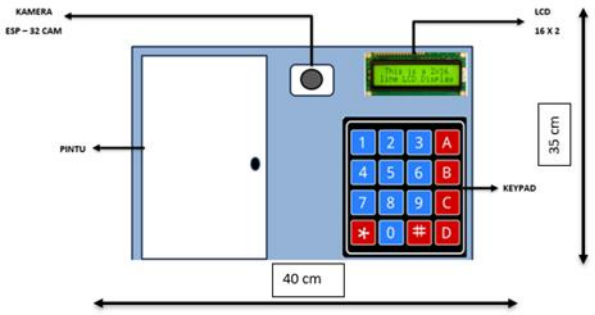
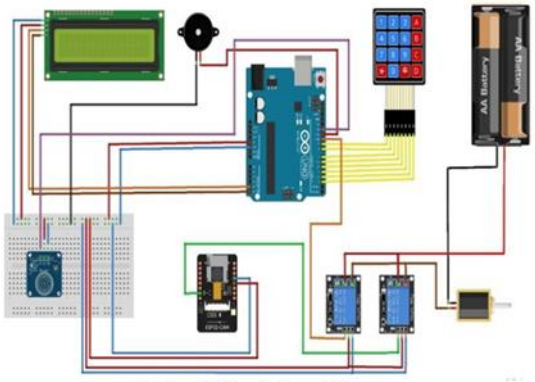


Gambar 1. 1 Rancangan Produk Tampak dari Depan

1. The product design includes a door for simulating the home door security system with face recognition using the ESP32-CAM. The door contains a solenoid to lock it.
2. Inside the enclosure, there is an ESP32-CAM module for face detection. The face data that has been input into the ESP32 system is used for the security system to process the detected face and control the solenoid to unlock the door.
3. There is a 16x2 LCD to display notifications of whether the face trying to access the door is recognized or not in the home door security system with face recognition using the ESP32-CAM.
4. There is also a keypad in the home door security system with face recognition using the ESP32-CAM, used as a second option to access the door besides using the ESP32-CAM. In this case, a pin is used to unlock the solenoid on the door.

B. Product Working Principle

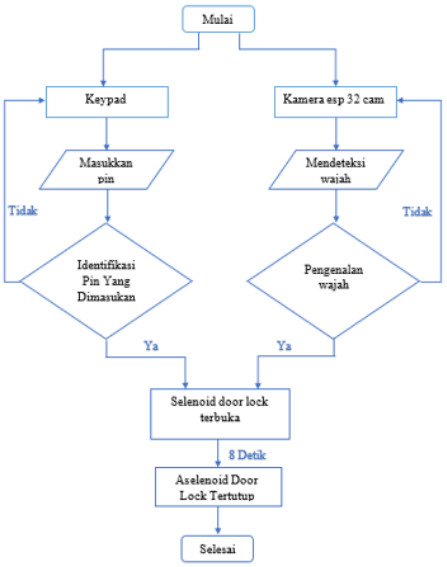
The working principle of the product involves several components, including Arduino Uno, ESP32-CAM, 16 x 2 LCD, breadboard, 5V relay, 10K ohm potentiometer, 4 x 4 keypad, solenoid door lock, 12 VDC adapter, and a buzzer. A 5-volt power source is connected to the breadboard, allowing power distribution to the components.



Gambar 1. 2 Cara kerja produk

1. ESP32-CAM receives power from the source, enabling the controller to operate. PIN 2 on the ESP32-CAM functions as the face detection output to the relay and is connected to PIN 10 on the Arduino.
2. This input is in the form of digital signals processed by the face recognition program on the ESP32-CAM. Meanwhile, PINs 2-9 are used as inputs from the 4 x 4 keypad for entering a password as the manual system of this prototype. PIN 12 on the Arduino is used as an input signal from the touch sensor.
3. The touch sensor also requires a 5-volt power supply provided by the Arduino Uno. PIN 10 functions as the output to the relay, which will be used to activate and deactivate the solenoid door lock. The contact COM on the relay connects to 12 V, and the NO contact on the relay provides 12 V to the solenoid door lock.

C. *Flowchart*



Gambar 1. 3 Flowchart

D. Variables and Operational Definitions

Variables in conducting research refer to attributes, characteristics, and other aspects of value from a person, object, or activity with specific types and are determined by the researcher to study and obtain the final result of the study. A variable is an element that can differentiate or change values. These values can vary over time for the same object or individual, or they can differ over time for different objects or individuals. In this study, the independent and dependent variables are as follows:

a. VIndependent Variables

Independent variables are variables that cause or influence, i.e., factors measured and manipulated by the researcher to determine the relationship between phenomena. In this study, the independent variables are:

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1. Number of data retrievals
2. Face Detection Time: The time required by the system to detect the presence of a face in front of the door.
3. Detection Range: The maximum range within which the system can successfully detect a face.
4. Wi-Fi Connection Speed: The speed of data transfer over the Wi-Fi connection used by the ESP32-CAM.
5. Face Database Capacity: The maximum number of faces that can be stored in the database for recognition.
6. Camera Quality: The resolution and quality of the images produced by the camera on the ESP32-CAM.
7. Lighting intensity: The impact of lighting on the system's ability to successfully detect a face.

If these key components are not available, the device cannot be implemented as a home door security system using the ESP32-CAM camera module. Implementation of the home door security system with face recognition using the ESP32-CAM is crucial.

b. Dependent Variables

Dependent variables are factors observed and measured to determine the impact of independent variables, factors that appear or do not appear or vary depending on what is introduced by the researcher. In this study, the dependent variables are:

1. Door Response Time: The time required for the system to open or close the door after successful face recognition.
2. Face Recognition Accuracy: The success rate of the system in correctly recognizing faces.
3. Door Security: The system's ability to prevent unauthorized access or manipulation of the door.
4. System Availability: The percentage of time the system is accessible and operational without failure.
5. Power Efficiency: Efficient use of power to prolong battery life or reduce power consumption.
6. Network Availability: The reliability of the network connection for communication with external devices or servers
7. User-Friendliness: The simplicity and ease of use of the system by the end-user.

These variables help evaluate the performance and effectiveness of the home door security system using face recognition with ESP32-CAM from various aspects.

E. Data Analysis Method

The data analysis method that may be used includes descriptive statistical analysis to summarize data characteristics, hypothesis testing to examine significant differences, regression analysis to evaluate the relationship between variables, and performance evaluation of face recognition algorithms.

It is crucial to plan the data analysis method carefully according to the research objectives or implementation of the home door security system using face recognition with ESP32-CAM. The right analysis method can provide valuable insights into the system's performance and effectiveness.

III. RESULTS AND DISCUSSION

Results and discussion cover the findings from data collection and presentation of data, which is a crucial part of preparing a report or conducting research. Any report or research, regardless of type, always uses data to present facts or information contained in the report. A simple yet accurate presentation significantly helps readers understand what is written in the report.

In the context of developing or building a home door security system using face recognition with ESP32-CAM, advancements in science and technology, particularly in the fields of electronics and informatics, are expected to improve the technology of room or home security systems, especially home door security systems. Door security technology has been widely developed to prevent and provide peace of mind for homeowners when leaving their homes. Several door security systems commonly used include CCTV cameras, fingerprint sensors, voice sensors, and RFID. However, as technology evolves, these security systems have revealed many weaknesses, such as frequent errors in fingerprint and voice sensors and many others. Based on these issues, to create a safer and more innovative home door security system, the author has developed a security system with face detection.

Based on the experiments conducted by the researcher, the data collected reveals the following results:

A. System Success Rate in Identifying Faces:

In the experiment with the home door security system using face recognition with ESP32-CAM, data was collected by inputting 5 types of face data into the ESP32-CAM system to unlock the solenoid on the door. In this test, 10 face variations were tested, with 1 face already recorded as a biometric key in the system, while the other 10 face variations were used to test the accuracy of face recognition.

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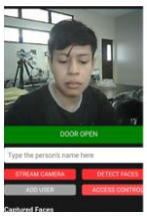
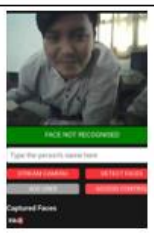
Tabel 1. 1 System Success Rate in Identifying Face

No.	VARIASI WAJAH KE-	TAMPILAN GAMBAR	KETERANGAN
1	Wajah ke-1 (Wajah kunci)		Terbaca
2	Wajah ke-2		Tidak terbaca
3	Wajah ke-3		Tidak terbaca
4	Wajah ke-4		Tidak terbaca
5	Wajah ke-5		Tidak terbaca
6	Wajah ke-6		Tidak terbaca
7	Wajah ke-7		Tidak terbaca
8	Wajah ke-8		Tidak terbaca
9	Wajah ke-9		Tidak terbaca
10	Wajah ke-10		Tidak terbaca

B. Accuracy Testing of ESP32-CAM under Different Light Intensity:

In the accuracy testing of the ESP32-CAM under different light intensities for the home door security system using face recognition, it is important to understand that lumens measure the light flux produced by a light source. Brightness or the luminance of a lamp or lighting device is measured in lumens. However, the perception of lighting is also influenced by other factors such as light color, lighting direction, and individual preferences. This test uses 3 different lighting variables:

- Dim: Typically ranges from 1 to 200 lumens. Lights with this low lumen level are suitable for creating a calm atmosphere or as ambient lighting that is not too bright.

- Moderate/Bright: Ranges from 200 to 800 lumens. Lights with this lumen level are suitable for everyday needs in many rooms, such as living rooms or bedrooms.

-Very Bright: More than 800 lumens. Lights with high lumen levels are usually used in areas that require intense lighting, such as kitchens, work areas, or family rooms.

In this data collection, 3 types of lighting variables were used (Dim, Moderate/Bright, Very Bright) with one-time testing of the same face to find the success data for the system's accuracy under different lighting intensities.

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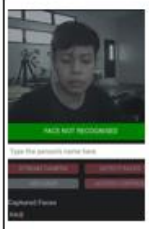
Tabel 1. 2 Accuracy Testing of ESP32-CAM under Different Light Intensity

PENGUJIAN	PENCAHAYAN	PENGAMBILAN FOTO	PEMBACAAN
1	Redup (200 Lumen)		TIDAK TERBACA DI CAHAYA 200 LUMEN
2	Cukup Terang (300 Lumen)		TERBACA DI CAHAYA 300 LUMEN
3	Sangat Terang (800 Lumen)		TERBACA DI CAHAYA 800 LUMEN

C. Accuracy Testing of the System for Effective Range of Face Identification with ESP32-CAM:

In the accuracy testing of the ESP32-CAM for the effective range of face identification in the home door security system using face recognition. In this test, 10 experiments were conducted with 10 different range variations used.

Tabel 1. 3 Accuracy Testing of the System's Effective Range for Face Identification

No.	JARAK(CM)	TERBACA	TIDAK
1	5	O	I
2	10	O	I
3	15	O	I
4	20	O	I
5	25	I	O
6	30	I	O
7	35	I	O
8	40	I	O
9	45	I	O
10	50	I	O

IV. DISCUSSION

Recommendations for further research include:

A. Lighting Optimization: Consider increasing ambient lighting in the face recognition area, such as LED lights, to ensure faces can be detected clearly under various lighting conditions.
B. Further Testing: Conduct more extensive testing with various environmental conditions and face variations (such as with glasses, hats, etc.) to ensure the system works consistently and reliably in different situations.
C. Data Security: Implement security measures to protect stored face data and data transmission from ESP32-CAM to the server or other devices. Data encryption is one important step that must be applied.

By applying these conclusions and recommendations, the home door security system based on face recognition with ESP32-CAM can become a safer, more reliable, and effective solution to protect homes from security threats.

V. CONCLUSION

The research aims to develop a prototype home door security system using face recognition technology based on ESP32-CAM.

A. Effectiveness of Face Recognition: The home door security system using ESP32-CAM face recognition technology has proven effective in identifying and authorizing access based on faces. This system provides a higher level of security compared to traditional methods like keys.
B. System Success in Handling Light Intensity Variation: The system developed performs successfully under light intensity variations ranging from 300 lumens to 800 lumens.
C. Understanding the Effective Range for Face Identification with ESP32-CAM: The effective range for using the face identification system was found to be between 25 cm and 50 cm.

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