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IMPROVED FACE DETECTION ACCURACY USING HAAR CASCADE CLASSIFIER METHOD AND ESP32-CAM FOR IOT-BASED HOME DOOR SECURITY

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ABSTRACT
Some people are very easy to open the door lock with just a small wire. This causes the house to be vulnerable to burglary and theft. In previous studies, there were still shortcomings such as the accuracy of facial recognition was not good, the time for the facial recognition process was very long and no action was taken if the camera caught an unknown person. This raises the need for solutions related to security systems that can monitor homes when something suspicious happens so that it can be prevented immediately. This study aims to create a home door security system using ESP32-CAM as face recognition. This face recognition can unlock the door automatically and if someone is caught on camera who is not known, the system will send a notification to the owner to follow up on this. The results of the face detection test using the Haar Cascade Classifier method that can distinguish a known face and an unknown face. The results of facial accuracy at a distance of 30 cm, 40 cm, and 50 cm with a light intensity of 130 lux obtained an average accuracy of 96.6%. The result of the average time required from the face sampling process until the face is recognized by the system is 21,50 seconds.

I. INTRODUCTION

VERY day activities sometimes require someone to leave the house empty, such as during work or school hours. This causes the house to be vulnerable to burglary and theft occurs, even though the house has been locked or tightly locked. Some people are very easy and skilled to open a door lock or padlock with just a small wire [1]. This requires a solution related to a security system that can monitor the house when something suspicious happens so that it can be prevented immediately.

Several studies that have been carried out related to home security using facial recognition include research [2] using a Logitech C270 webcam as a face image taker. The system works by extracting faces that have been detected and applying face recognition with the eigenfaces as a means of facial recognition between homeowners and thieves in real-time. The results of this study the system can recognize facial images at a distance of 25 cm with a success rate of 90% with an average success of 72.5%, but in this study the accuracy level is still not good for door security. In research [3], the system uses a histogram of oriented gradient as the face image to be extracted. After obtaining the value of facial features, it will be classified using k-Nearest Neighbor. The results of this study obtained facial recognition accuracy at a distance of 40 cm, which is 87.5%, but the average time required for the face recognition process is very long, which is 13.29 seconds. In research [4], using ESP32-CAM as a camera for taking facial images. The system can detect faces and ensure that the one who opens the door is the one who has access rights as the owner of the house. The results of this study the system will work to detect faces that have been registered so that the door lock will open for 5 seconds and will close automatically after 5 seconds but in this study no action was taken if the camera caught an unknown person. In research [5], using the Triangle Face method based on Raspberry Pi. This house door security system has the advantage of increasing security in opening the door of the house without using the house key. In this study, the use of the Haar Cascade Classifier feature with OpenCV is used as a programming function for face detection. From the results of the first test, the face accuracy level is 92% with 104 lux lighting and the second test results have 84% facial accuracy with 53 lux lighting. In research [6], the method used is the Haar Cascade Classifier which compares unregistered human face objects with stored facial data. The system will open the door if the data matches the dataset. The results of the tests carried out 90 times, with 2 recognized faces and 2 unrecognized faces, the camera-to-object distance of 30 cm, 40 cm, and 50 cm obtained an accuracy of 91.11%. In research [7], stated that a system that uses Haar Cascade can detect faces accurately and efficiently. The accuracy of face detection using the haar cascade classifier method is 75%. The

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entire system has been proven to work well in detecting and taking attendance objects correctly. In research [8], the system changes the input color image into a gray image using the OpenCV library. The position of the face is greatly influenced in detecting faces. This system cannot detect faces that have a non-frontal position. Based on the test results on face detection using the Haar Cascade Classifier method, the total accuracy obtained is 90% from the input image that has a face object with a frontal position, while an accuracy below 50% is obtained from the input image that has a frontal face object and not frontal at all. In research [9], the system using the haar cascade method still has shortcomings in lighting. If there is too little light in the captured image in real time, the face cannot be recognized and this system can still recognize more than one face object. In research [10], the system used for the face detection and recognition process uses the Haar Cascade Classifier method which identifies human faces accurately. The Haar Cascade classifier is able to perform better facial recognition than the LBP algorithm and has good coverage for future implementations.

In this study the authors developed a home door security system using ESP32-CAM as facial recognition with the Haar Cascade Classifier. The Haar cascade classifier method has the advantage of very fast computation, because it only depends on the number of pixels in rectangle of an image. The ESP32-CAM equipped with a flash will help with lighting and improve facial recognition accuracy. This system is equipped with fingerprint sensor as a second security system to unlock the door. Process Facial recognition is accessed through the website. In this system, if a known face is detected in the database, the door lock will automatically open and if the face is not recognized, it will provide a notification in the form of a photo via telegram. In addition, there is a feature to unlock the door via the telegram application that can make it easier for homeowners when guests arrive.

II. METHODOLOGY

A. Data collection

In this study, testing the face detection system used 12 people's facial data, 6 of which were registered in the database. The distances used are 30 cm, 40 cm, and 50 cm with a light intensity of 130 lux. In the face sampling process 7 times for 1 person until the face is recognized by the system. With this test, face detection accuracy will be obtained.

B. Face Recognition

Face recognition is one of the biometric technologies that has been used in various security systems such as the recognition of the retina of the eye, the iris of the eye, and the recognition of fingerprints. Face recognition is also a part of computer vision applications, which can carry out assessments and assessments only from digital photos or video frames, only by comparing facial features from photo data, with facial data in the database [11].

C. Haar Cascade Classifier

Haar Cascade Classifier is a rectangular feature that gives a certain indication on an image [12]. The Haar cascade classifier was first conceived by Paul Viola and Michael John. This method has the advantage of very fast computation, because it only depends on the number of pixels in the square of an image not every pixel value of an image [13]. The approach to detect objects in images combines 4 main keys, namely Haar like feature, Integral image, Adaboost learning and Cascade Classifier [12].

1) Haar Like Feature

Haar Like Feature is used to detect objects in digital images. The presence of haar features is determined by subtracting the average pixel in the dark area from the average pixel in the bright area. If the value is at the specified threshold, it can be said that the feature exists. There are 3 types of rectangular features, namely Two-rectangular feature, Three-rectangular feature, Four-rectangular feature [12].

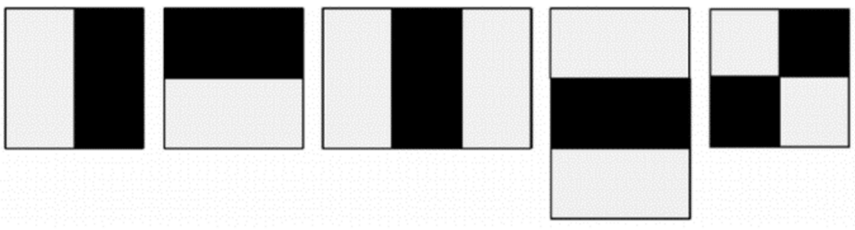

Figure 1. Haar Like Feature

2) Integral Image

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Integral Image is used to add small units together, in this case the small units are called the value of pixels. The value of the integral at each pixel is the sum of all the pixels from the top left to the bottom right. The process of finding the value of this feature is done iteratively starting from the top left corner to the bottom right corner with a shift of x and y. The smaller the values of x and y, the more accurate the detection of the image [12].

3. Adaboost Learning

Adaboost is used to combine many classifiers into one powerful classifier. The Adaboost algorithm works to find features that have a high level of differentiation. This is done with every feature between facial and non-face that is considered the best feature [12].

4. Cascade Classifier

The characteristic of haar cascade is the existence of a cascade classifier. In this algorithm there is a classification level to determine whether or not there are features of facial objects in the selected features. Each sub-image is compared with each feature at each stage. If the result of the feature value does not meet the desired criteria, then the result is rejected and the sub-image will move to the next sub-image and perform the same calculations as the previous process. In the next process, the sub-image results are detected as faces and proceed to the next sub-image. In the end got a strong potential detected as a face [12].

D.ESP32-CAM

ESP32-CAM is a WiFi/Bluetooth development board with ESP32 microcontroller and camera. This microcontroller provides features that can be used by anyone, or can be said to be open source, one of its features is used to take photos, face recognition and face detection [14]. The ESP32-CAM has built-in 520KB of SRAM and 4MB of external PSRAM [15].

III. RESULTS AND DISCUSSION

A. System Overview

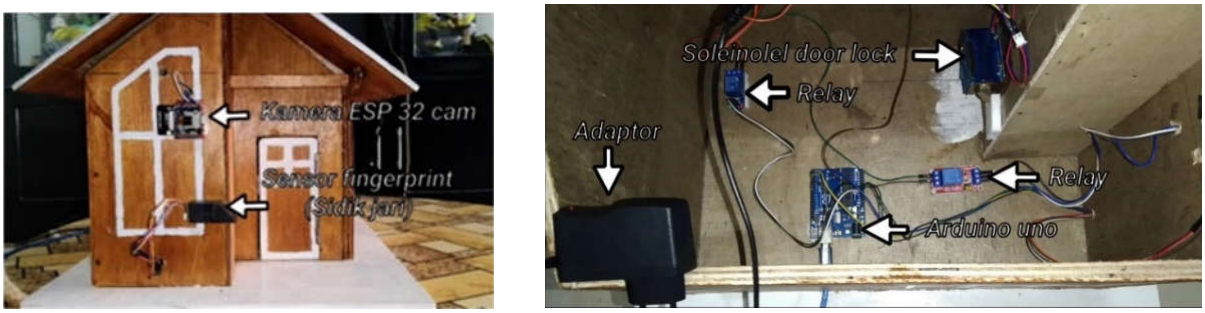

Figure 2. *Smart Door Lock Prototype*

In Figure 2 the design of the house door system is made using the Haar Cascade Classifier method as a face detector. Detected faces are those that are facing forward and those that are not blocked by masks or other objects. Then the system will identify the face whether the user's face is allowed to enter or not. Furthermore, if it is not allowed to enter, it will send a notification in the form of a face photo to Telegram via the internet which will be sent to smartphone users. After that the user can control the door lock via a smartphone to allow the person to enter or not. Some of the functions and features of this device include:

1. The system is able to unlock if the system detects a face registered in the database.
2. The system is able to unlock by using fingerprint.
3. The system is able to open and close the lock via a smartphone.
4. The system is able to send notifications to the homeowner.

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A. *System Block Diagram*

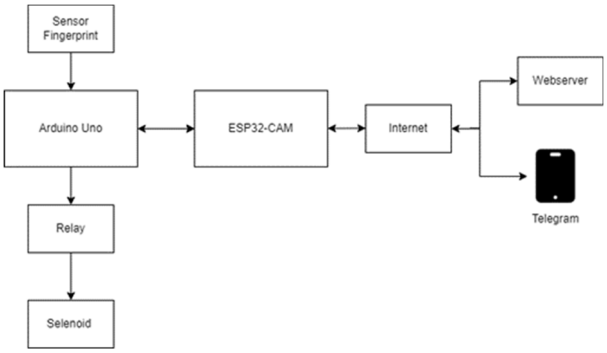

Figure 3. *System Block Diagram*

The input section consists of an ESP32-CAM to perform a facial recognition system and a fingerprint sensor that functions as a fingerprint reader as a second security system. In this system there are 2 controllers used, namely ESP32-CAM and Arduino. Arduino is used for the pin input system on the fingerprint sensor. In the face recognition process takes place on a webserver with the IP used 192.168.1.13. In this system, if a face is recognized it will give an open solenoid output and if the face is not recognized it will send a photo notification via telegram. After that the user can control the door lock via telegram to allow the person to enter or not. Block diagram system can be seen in Figure 3.

C.System Workflow

The flowchart will explain the face recognition authentication process to unlock the door automatically. The user must first to do wifi connection. After that, if the wifi connection is connected, the system will take a picture from the camera and send the image file to the ESP32-CAM. Next do face detection. After that the system will send the results of face detection if the face is registered then the solenoid will open and if the face is not registered it will send a face photo notification via telegram. After the user opens the notification the user can control the door lock to allow the person to enter or not. Then if the wifi connection is not connected, the user's error face detection system can access it with a fingerprint to unlock the door by doing a fingerprint scan. If a fingerprint is detected, the solenoid will open and if it is not detected, the solenoid will be closed. How it works can be seen in Figure 4 below.

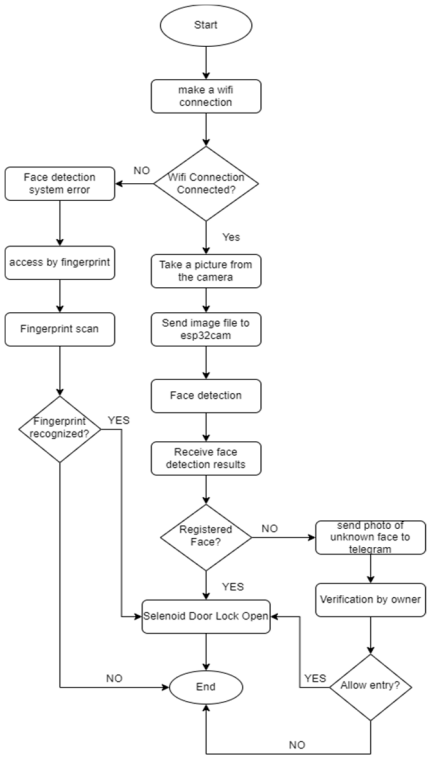

Figure 4. *Developed System Workflow*

D. *Functionality Testing*

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1) The system is able to unlock if the system detects a face registered in the database

At the bottom of this webserver there is a start stream button which is used to run the camera and enroll faces button, to take 7 face samples for 1 person which will be used as data to be stored by the system. If the face is recognized by the system then on that face there will be a green box that says the face is recognized and the door lock will open and if the face is not recognized by the system then on that face there will be a red box that says the face is not recognized and the door lock is in a state closed. The following are the results of testing the face detection function which can be seen in Figure 5.

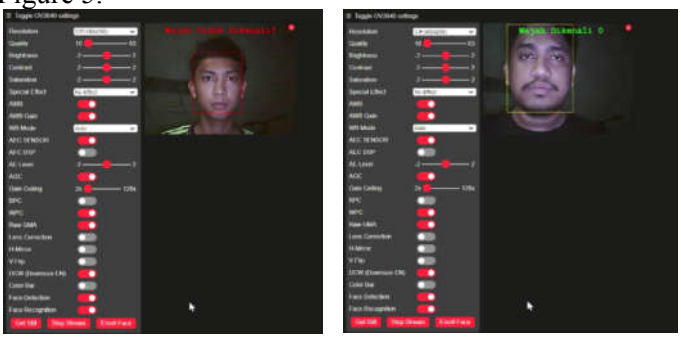

Figure 5. *Face Detection System Results*

2) The system is able to unlock by using fingerprint

At the time of fingerprint registration, will be asked to enter the fingerprint image data into the fingerprint memory along with the ID number for the user. After the ID number and fingerprint image data have been stored in memory, the user can access the system. Next do the test for fingerprint. If the fingerprint is detected to match then the door lock will open and if the fingerprint is detected not match then the door lock is closed. The following are the results of testing the fingerprint function which can be seen in Figure 6.

Figure 6. *Fingerprint Test*

3) The system is able to open and close the lock via a smartphone

The application used is Telegram. To control the system of opening and closing door locks, a bot is made in the telegram application. To create a bot in the telegram application, the user must search for a bot with the name BotFather. Then type the command '/newbot' then the user will be asked to write the name of the desired bot. Then enter the username for the bot. After that the user will be given a token from the bot. Next, do a test to send commands to the telegram bot which is made if the user sends the command '/unlock' then the door lock will open and if the user sends '/close lock' then the door lock is closed. The following are the results of testing the Open and Close Door Locks Via Telegram function which can be seen in Figure 7.

Figure 7. *Testing Open and Close Door Locks Via Telegram*

4). The system is able to send notifications to the homeowner

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When the person's face is not recognized, the system will send a notification to Telegram in the form of a photo of that person's face. The following are the results of testing the Notification Via Telegram function which can be seen in Figure 8.

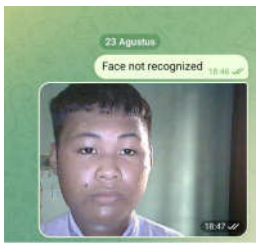

Figure 8. *Test Notification Via Telegram*

E. Face Detection System Test Results

This test uses the Haar Cascade Classifier method with 6 faces stored in the database and 6 faces not stored in the database. In this test, 10 experiments were carried out to ensure the system could perform facial recognition well. The following are the results of the facial recognition test on the system, which can be seen in Table I .

Table I.
Face Detection System Test Results

th Person Testing	Distance (cm)	Light intensity (lux)	Face Status	Number of Trials	Results		Success Accuracy
					Known	Unrecognized	
1st Person Test	30	130	Registered	10	10	0	100
2st Person Test	30	130	Registered	10	10	0	100
3st Person Test	30	130	Unlisted	10	0	10	100
4st Person Test	30	130	Unlisted	10	0	10	100
5st Person Test	40	130	Registered	10	10	0	100
6st Person Test	40	130	Registered	10	10	0	100
7st Person Test	40	130	Unlisted	10	0	10	100
8st Person Test	40	130	Unlisted	10	0	10	100
9st Person Test	50	130	Registered	10	10	0	100
10st Person Test	50	130	Registered	10	10	0	100
11st Person Test	50	130	Unlisted	10	2	8	80
12st Person Test	50	130	Unlisted	10	2	8	80
Average Accuracy (%)							96,6

From the test results using the Haar Cascade Classifier method in Table I the system can recognize registered and unregistered faces at a distance of 30 cm, 40 cm, and 50 cm with a light intensity of 130 lux, the average accuracy is 96.6%. However, at a distance of 50 cm, the system still fails to recognize faces that are not registered. The following results of the comparison of facial accuracy can be seen in table II

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Table II.
Facial Accuracy Results

research	Method	Average Accuracy
	Metode *Haar Cascade Classifier*	96,6 %
research [6]	Metode *Haar Cascade Classifier*	91,11%

The results of the comparison of data using the Haar Cascade Classifier method with an ESP32CAM camera, at a distance of 30 cm, 40 cm, and 50 cm obtained an accuracy of 96.6% compared to research [6] using the Haar cascade Classifier method with a webcam camera, at a distance of 30 cm, 40 cm, and 50 cm obtained an average accuracy of 91.11%. Thus the ESP32-CAM camera has a higher level of accuracy in recognizing faces.

F. Fingerprint Sensor Test Results

This test was carried out by 5 people with registered fingerprint data and 5 people with unregistered fingerprints. In this test, 2 different fingers were used for each person with 10 trials. Here are the results of testing the fingerprint sensor. The following are the results of testing the Fingerprint Sensor which can be seen in Table III.

Table III.
Fingerprint Sensor Test Results

Name	Fingers used	Fingerprint Status	Results	Number of Trials	Accuracy
Fadel	Thumbs, Fore-finger	Registered	Detected	10	100
Rosita	Forefinger, Ring finger	Registered	Detected	10	100
Rifdah	Middle finger, Ring finger	Registered	Detected	10	100
Nauval	Thumbs, Fore-finger	Registered	Detected	10	100
Farhan	Middle finger, Pinkie	Registered	Detected	10	100
Haikal	Thumbs, Pinkie	Unlisted	Not detected	10	100
Ghailan	Pinkie, Forefin-ger	Unlisted	Not detected	10	100
Rian	Middle finger, Thumbs	Unlisted	Not detected	10	100
Andika	Forefinger, Mid-dle finger	Unlisted	Not detected	10	100
Ferdi	Thumbs, Fore-finger	Unlisted	Not detected	10	100
		Average Accuracy (%)			100

From the test results in Table III. The fingerprint sensor can recognize registered and unregistered fingerprint data. The average accuracy obtained is 100%.

G. Test Results Response Time Face Detection Process

This response time test was carried out 10 times to try to unlock the door starting from the face sampling process until the solenoid opened using the program. The following are the results of testing the response time of the face detection process which can be seen in Table IV.

The test results in Table Table IV the average time needed to unlock the door from the face sampling process until the face is recognized by the system is 21,50 seconds. However, the longest time is in the range of 24 to 28 seconds in each test. This is also greatly influenced by the level of stability of the internet provider used.

Table IV
Face Detection Response Time Test Results

Trial to-	Response Time (Second)	Solenoid
1	14,94	Open
2	28,17	Open
3	25,14	Open
4	20,51	Open
5	22,11	Open
6	20,54	Open
7	15,81	Open
8	24,17	Open
9	20,84	Open
10	22,83	Open
Average Time		21,50

IV. CONCLUSION

In this study, a face detection system was successfully created using the Haar Cascade Classifier and ESP32-CAM for Internet of Things-based home door security. This system is able to unlock if the system detects a face registered in the database, is able to unlock doors using fingerprints, is able to open and close door locks via smartphones and is able to send notifications to homeowners. The results of facial accuracy using the Haar Cascade Classifier method as face detection with a distance of 30 cm, 40 cm, and 50 cm with a light intensity of 130 lux obtained an average accuracy of 96.6%. The result of the average time required from the face sampling process until the face is recognized by the system is 21.50 seconds.

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