Research Article

Smart Home Monitoring House Fence Using Face Recognition Based On The IoT

[1*] Ega Nurwani Faisal, [2]Jumadi M Parenreng, [3]Muliadi

[1,2,3] Department of Computer System Engineering, Universitas Negeri Makassar, South Sulawesi, Indonesia

* Corresponding Author: nurwaniega@gmail.com

Abstract: Technological developments have become very important in modern life, including the security sector. Currently, there is more and more sophisticated equipment and security systems based on the latest technology; the increasing crime rate, especially theft and robbery, encourages the need for a more effective and efficient security system. This research aims to build a prototype for smart home monitoring of home devices, namely house fences, using facial recognition based on the Internet of Things. The dataset required in this research is 11,500 facial images in 5 categories. Training of the machining learning model using a convolutional neural network was carried out several times to produce a model with the best accuracy. The test was carried out on 122 samples and produced an accuracy value of 86% and an average telegram response of 7 seconds, so that it could monitor house fences in real time.

Keywords: security, smart home, face recognition, internet of things, convolutional neural network

Citation: Faisal, E. N., Parenreng, J. M., & Muliadi. (2025). Smart home monitoring house fence using face recognition based on the IoT. *Iota*, 5(3). https://doi.org/10.31763/iota.v5i3.957

Academic Editor: Adi, P.D.P

Received: June 06, 2025

Accepted: July 07, 2025

Published: August 01, 2025

Publisher's Note: ASCEE stays neutral about jurisdictional claims in published maps and institutional affiliations.

1. Introduction

In modern times, computers are developing very rapidly and are one of the fields that play an important role in several aspects of human life, including the field of security. Currently, there is more and more sophisticated security equipment and systems based on the latest technology. The increasing number of crimes, especially theft and robbery, encourages the need for a more effective and efficient security system, especially in this IT era. A digitally connected security system that can be monitored from anywhere is necessary.

Internet of Things (IoT) is a term that has recently been discovered, but few understand its meaning of this term. The Internet of Things can be generally defined as objects around us that can communicate with each other through the internet. The Internet of Things expands the benefits of being connected through a continuous internet connection. (Supiyandi et al., 2023). In 2021, the design of the prototype of the automatic gate system using a Bluetooth device by this study was able to detect the maximum transmission distance from the HC-05 Bluetooth module to the Bluetooth smartphone on Android, measured in open space is as far as 10 metres with an average execution time of less than 1 second.

This research uses the Haar cascade face recognition method for home security controlled by Arduino. The system will detect the homeowner. If the homeowner is detected, then the fence will open, but if the face is not recognised, then the system will send a notification via telegram bot. With this system, the house fence will be able to open automatically using facial recognition. This will increase home security and also make it easier for users, so they don't need to get out of the vehicle to open the gate.

2. Theory

2.1 Parameters and Component

Some of the essential parameters in image detection as well as the tools, hardware, and parameters used in this research are represented as the following points: [1] Image: An image is a representation, likeness or imitation of an object or thing Mathematically, an image is expressed as a continuous function of light intensity on a two-dimensional plane. The visible image is the light reflected from an object. Images can be divided into two, namely continuous images obtained from optical systems that receive analogue signals (human eyes and analogue cameras) and discrete (digital) images produced through the digitisation process of continuous images. [2] Monitoring System: Monitoring is a foreign verb derived from the word monitor. Monitor is also an absorption word used in Indonesian. Monitor, according to the (*Great Dictionary of the Indonesian Language*) is a person who monitors, a device for monitoring (such as a receiver used to display images taken by a television camera, a device for observing biological conditions or functions, a device that monitors the work of a system, especially a computer system, etc.). [3] Internet of Things: The Internet of Things is a concept in which an object can transfer data over a network without the need for human or human-to-computer interaction. The Internet of Things has developed rapidly through the incorporation of wireless technology, microelectromechanical systems (MEMS), and the Internet. [4] Arduino Nano MCU: Arduino Nano is a microcontroller board that has a compact size, complete with features that support breadboard users. Arduino Nano board uses an Atmega328 microcontroller (for Arduino Nano version 3x) or has capabilities comparable to Arduino Duemilanove. Unlike the Arduino Duemilanove type, the Arduino Nano does not have a barrel jack type DC connector, but is connected to the computer via a Mini-B USB port. This Arduino Nano device is designed and manufactured by the Gravitecth company.

Moreover, [5] Haarcascade: Haar cascade is a technique used for object detection, especially in face recognition, developed by Paul Viola and Michael Jones in 2001. This method uses a Haar feature-based algorithm and a cascade-based classifier to detect objects in images or videos. The term 'Haar' refers to the box-shaped mathematical function applied in this method. [6] Python: Python is a multipurpose interpretive programming language with a design philosophy that focuses on code readability. Python is claimed to be a language that combines capability, ability with a very clear code syntax, and comes with the functionality of a large and comprehensive standard library. Python supports multiple programming paradigms, mainly but not limited to object-oriented programming, imperative programming, and functional programming. Python can be used for a variety of software development purposes and can run on various operating system platforms. [7] Telegram: Telegram is a chat messaging application like WhatsApp, Line, and BBM. Telegram uses the MTProto protocol, which has been tested for its level of security due to the end-to-end encryption process used. Just like similar applications. Telegram can share messages, photos, videos, and tag locations between fellow users.(Novansyah et al., 2021).

Furthermore, the formula of Haarcascade is shown as in equation 1. Where simple rectangular patterns capture intensity differences in image regions. And added with the integral image function as in equation 2. Then make the rectangular sum into a constant time value using four array references as shown in equation 3.

$$\text{Feature value}=\sum(pixels\ \ in\ \ white\ \ region) - \sum(pixels\ \ in\ \ black\ \ region) \quad [1]$$

$$I\ (x,y) = \sum_i o^x \sum_j o^y i(i,j) \quad [2]$$

$$Sum=I(D)+I(A)-I(B)-I(C) \quad [3]$$

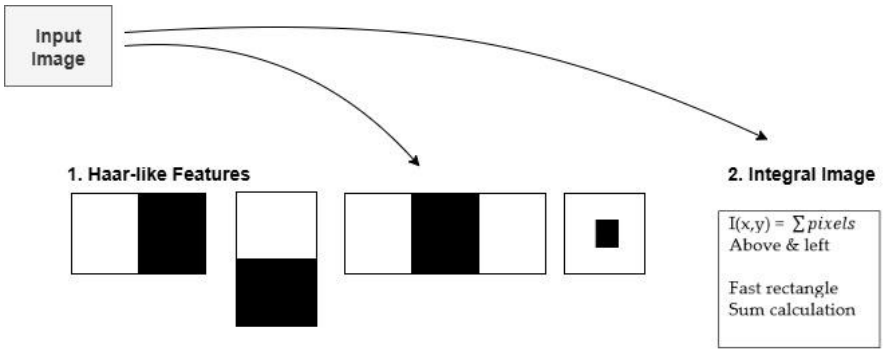

Figure 1. Haarcascade Diagram

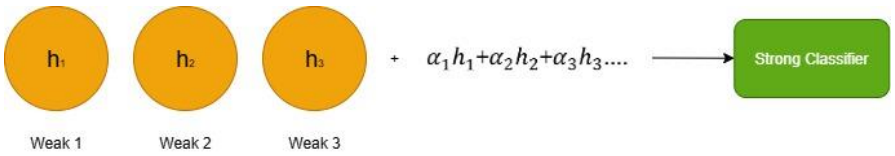

Figure 2. AdaBoost Training

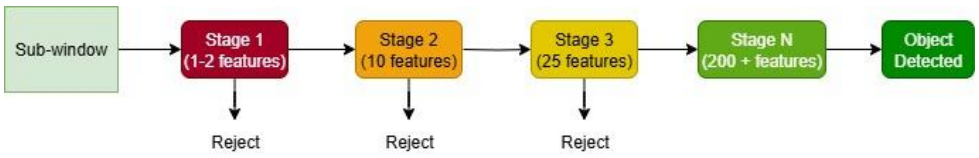

Figure 3. Cascade Structure

Furthermore, AdaBoost is shown in equation 4, and Weak Classifier is shown in equation 5, while Weight Update is shown in equation 6.

$$H(x) = sign \ \ (\sum_t \ \alpha_t \, h_t(x)) \quad [4]$$

$$H(x) = 1 \ \ if \ \ pf(x) < p\theta, else \ \ 0 \quad [5]$$

$$w_{t+1,i} = w_{t,i}\beta_i^{\,ei} where \ \ \beta_t = \frac{\varepsilon_t}{1-\varepsilon_t} \quad [6]$$

Research on image processing and specifically on face recognition has been completed by several researchers around the world in the last three years, who focus on developing accuracy and also on device technology, such as cameras, and other factors that are essential in sensor readings, datasets, and data complexity. some of the authors are as follows: Puji, M. N., et.al. (2025), Lee, C. S., & Mun, H. K. (2023), Asri, M. M., et.al.(2023), Aprianto, F., et al. (2024), Yolanda, D., et.al.(2023), Patil, M. N, et.al.(2024), S, J., Kumar, et.al.(2024), Geetharani, T. O., P, B., L, C., Naik, S. R., & A, Y. (2025), Salsabila, N., Siswanto, A., & Bayuaji, L. (2025), Raghu, N., Miah, I., & Tonmoy, A. B. R. (2023), G. Rajeshkumar, et.al. (2023).

3. Method

The system architecture in Figure 4 describes the general description of the fence monitoring system for the security of a room. The required system is a fence monitoring system that uses IT technology (Oleksiyuk, T., 2025). Ojha, R.R., et.al. (2025), Kim., S. et.al. (2025), Thomas, P.J.N., et.al. (2025), Ji, H. et.al.(2025), Maruthirao, S. & Khayum, P.A. (2025), Qian, J. et.al. (2025), Ul Haq, M. et.al. (2025), Matsufuji, K. et.al. (2025), Pattnaik, I. et.al. (2025)). Some of the technologies used in this system are Arduino which acts as a microcontroller for controlling and processing the system, a webcam as a camera that will take pictures, and also a telegram application as a notification to the owner when there is an unrecognised face in front of the fence while sending a capture of the face through a telegram bot. The webcam is used to take pictures and detect faces in front of the fence. After that, the face will be inputted and the database that has been made before. If the data has been retrieved and matches the database, it will make a relay to control and drain electricity to the selenoid, and the fence will automatically open by itself and be directly monitored through the Telegram application.

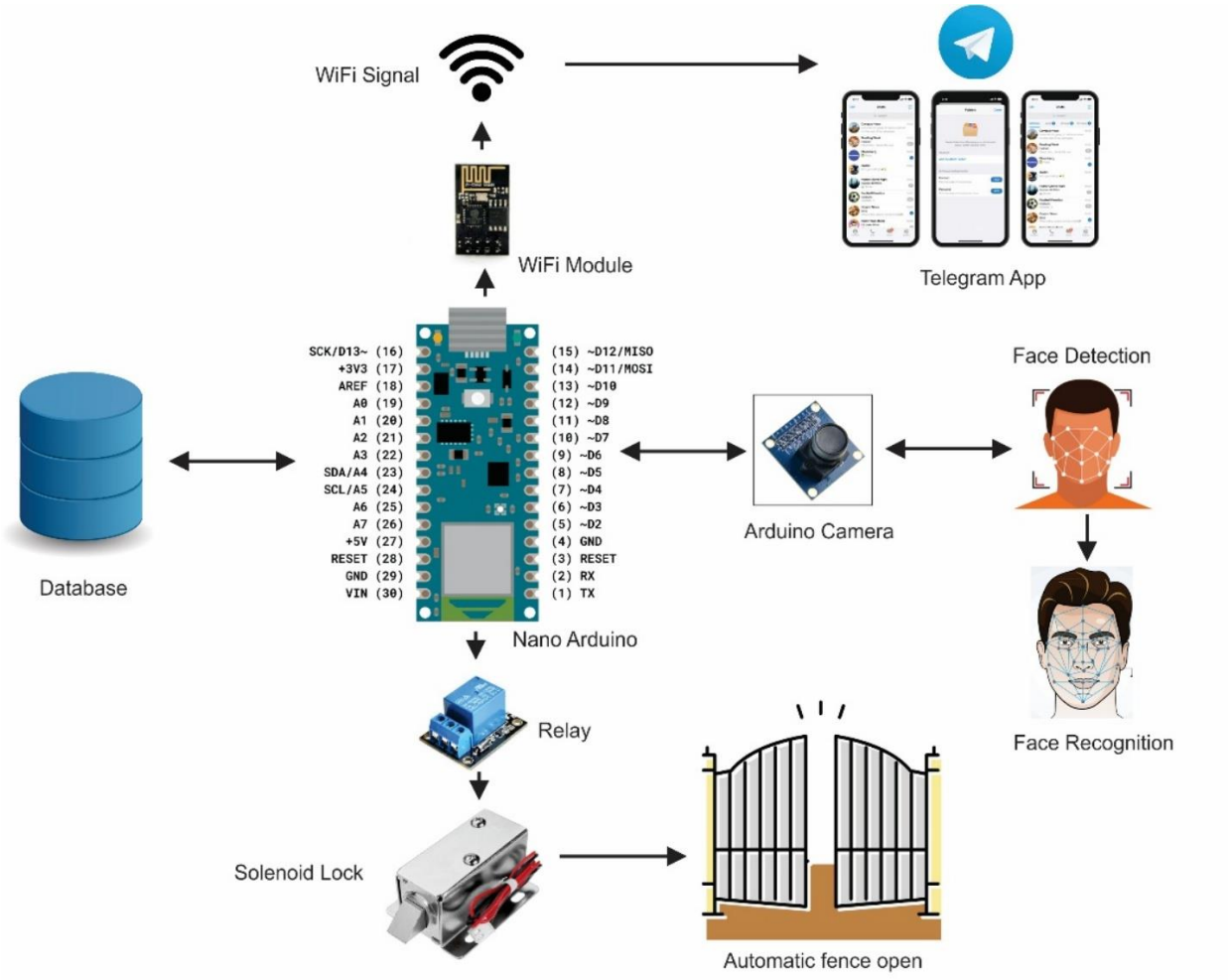

Figure 4. Architecture System

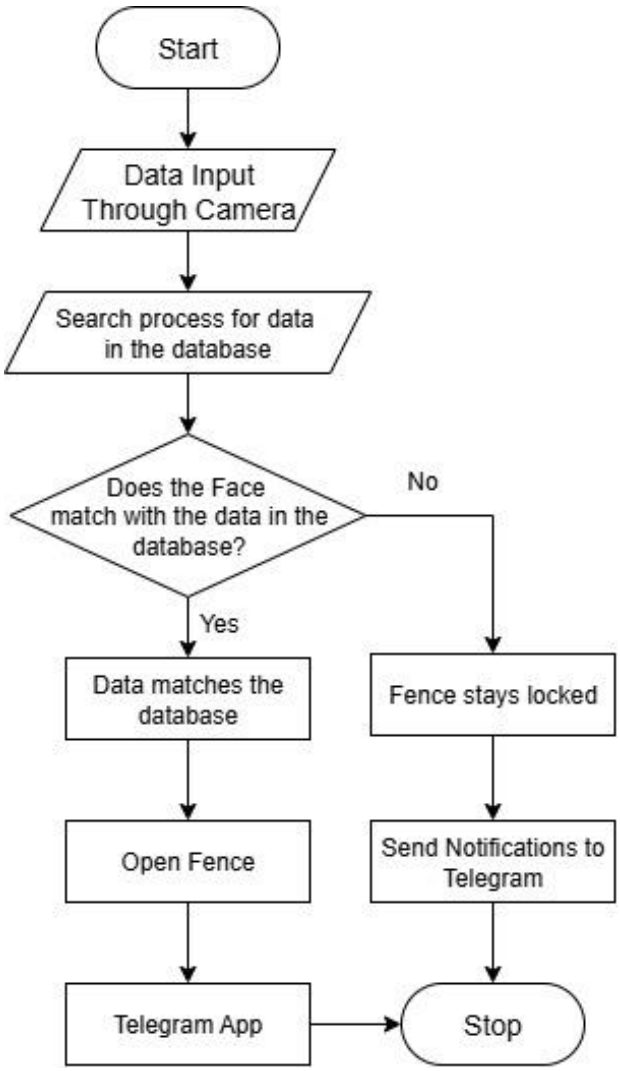

Figure 5. Overall System Flowchart

In Figure 5 is the Flowchart of the whole system, explaining that the user must enter the fence first by entering data to the camera, then searching for data on the face through the database, then whether the face matches the data in the database, if the face data matches the database then the fence will automatically open, if the face does not match then a notification will appear in the telegram and the fence will be locked.

4. Result and Discussion

This research produces a tool in the form of a home fence monitoring prototype using face recognition based on the Internet of Things (IOT). In more detail, the research is described as follows:

4.1 Prototype System Design

The design of the prototype system in this study uses an application to design the mechanical system of the house gate. Figure 6 is the design of the mechanical design of the house fence gate. This prototype uses components including Arduino, 5-volt relay, LCD, DC motor, selenoid door lock12v. The Prototype system works as shown in Figure 6.

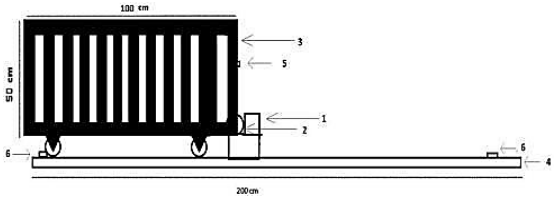

Figure 6. Prototype System

4.2 Dataset Collection

The dataset was collected using a 720p resolution web camera. Researchers collected a dataset of 11,500 facial images categorised into 5 categories. The categories are ega, as many as 2,000 facial images; ayu, 2,000 facial images; hikma, 2,000 facial images; dilla, 2,000 facial images; and suspicious, as many as 3,500 datasets. Dataset collection using Python, using OpenCV face detection in Python. The dataset was taken under conditions during the optimal light and secondly during the day and evening. The dataset collection used in this research can be seen in Figure 7.

Figure 7. Dataset Collection

The dataset in Figure 7 will be mined to produce a new model that will be applied to the system. After the dataset is collected, it will then be labelled according to the category. In this case 5 categories: Ega, Hikma, Ayu, Dillah, and Unknown. After the labelling is done, the dataset will be uploaded to Google Drive to facilitate access when training data using Google Collaboratory.

4.3 System Settings

System testing includes testing the prototype system, starting from the hardware, software, and the overall system. Table 1 is the Hardware Condition during testing. Testing is done to check the function of each component used in the research, namely the Arduino, webcam, relay, and solenoid. Arduino acts as the main microcontroller whose role is to run the entire work of the home gate system. The entire system work process that is directly related to the security function of opening and closing the house gate is carried out by Arduino.

Table 1. Hardware Condition

Hardware type	Indicator	Condition	
		Good	Bad
Arduino Nano	Port name	√	
	GND	√	
	Power	√	
	USB Connection	√	
Web Cam	USB Cable	√	
	Image Quality	√	
Relay	Lamp Indicator	√	
	Pin	√	
Solenoid	Pin Port	√	
	Open-Close	√	
LCD	LCD Pins	√	

4.4 Software

Testing is done to check the functions used; the test results can be seen as following Table 2.

Table 2. Software Condition

Software type	Indicator	Condition	
		Good	Bad
Python Application	Connection	√	
	Face Detection	√	
	Arduino Control	√	
Arduino IDE	Connection	√	
BOT Telegram	Receive and Send Images	√	

4.5 Face Detection

When the webcam is turned on, the face detection process is then carried out. This face detection aims to make the camera act as a sensor. Face detection uses the Haar cascade method. The Haar cascade algorithm is used in making this application is as face detection in the image. The result of Face Detection can be seen in Figure 8.

Figure 8. Face Detection

The script snippets and explanations on face detection are as follows, this Pseudocode 1.

```
1. Import Library
  - Cv2: OpenCV library for image processing and video. Numpy: Library for
  - array manipulation and numerical operations
  - TensorFlow: Library for building and running machine learning models
2. Load Model and Classification
  - CascadeClassifier: load Haar Cascade model for face detection from XML
    file
  - Load_Model: Load pre-trained face recognition model from H5 file
3. Webcam Initialisation
  - Vidiocapture0: initialises video capture from webcam
  - Set3(3,1280) and set(4,720) : set the video width and height
4.  Font and Threshold Settings
  - Font: set the font type of the display text in the video
  - Threshold: Specifies the confidence threshold for face classification.
    If the prediction probability is below this value, the face is
    considered unrecognised.
```

---------- Pseudocode 1 ----------

4.6 Face Detection with distance testing

Figure 9 explains that the distance of the face with 50 cm, 75 cm, 100cm, and 120 cm then the detection results are perfect, while the distance of 150 cm then the detection results are declared undetectable due to light conditions, and factors from the Webcam itself. At a certain distance, the webcam can no longer e. Face testing with time.

Table 3. Face Detection by time

Time	Detection Result
Pagi (6-10)	Detected
Siang (11-14)	Detected
Sore (15-17)	Detected
Malam (18-22)	Not Detected

The test in Table 3 explains that the detection time in the morning (06-10) detection is perfect, the detection results during the day (11-14) detection is still perfect, as well as in the afternoon (15-17) detection is still perfect, and detection at night (18-22) detection results are not perfect.

Jarak (cm)	Hasil	Deteksi
50 cm	Terdeteksi	
75 cm	Terdeteksi	
100 cm	Terdeteksi	
120 cm	Terdeteksi	
150 cm	Tidak Terdeteksi	

Figure 9. Face Detection with different distances

Face detection matching tests are carried out to determine the level of accuracy in the system that has been made. This test can be done by testing several facial image detections used. This test can be done as many as 122 test data using random samples. In this test, using 4 people who can be recognised as home fence access holders, namely Ega, Hikma, Dilla, and Ayu, and 10 random people as unrecognised people, random testing is carried out. Table 4 shows Face Detection Accuracy testing.

Table 4. Face Detection Accuracy Testing

Actual	**Predicted**				
	Ega	*Hikma*	*Ayu*	*Dillah*	*Not Taken*
Ega	16	1	0	0	1
Hikma	1	16	1	0	1
Ayu	1	0	14	1	0
Dillah	0	0	1	11	1
Not Taken	4	1	2	1	48

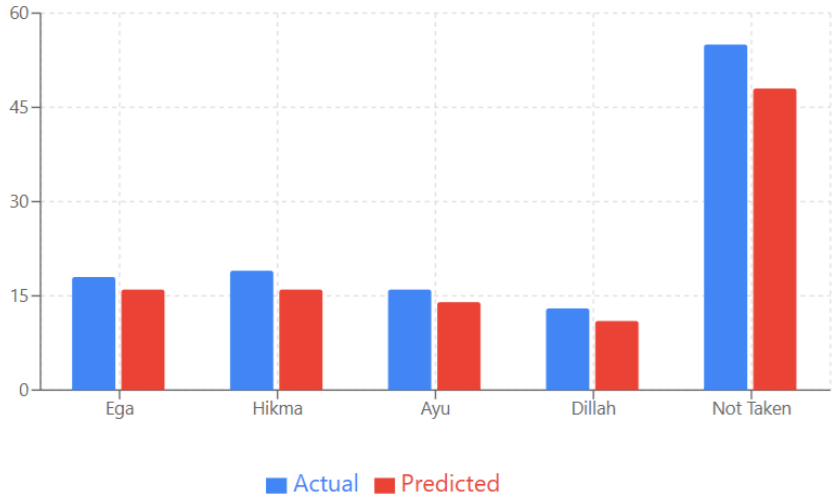

Figure 10. Actual vs Predicted

Based on Figure 10, it can be calculated the value of accuracy, precision, recall, and F1-Score in tests that have been carried out on the following 122 sample data. The accuracy formula and the result can be seen in equation 1.

$$\text{Accuracy} = \frac{TP}{Total\ \ Data} x\ \ 100\% \quad [1]$$

$$\text{Accuracy} = \frac{16+16+14+11+48}{122} x\ \ 100\%$$

$$\text{Accuracy} = \frac{105}{122} x\ \ 100\%\ \ Accuracy = 86\%$$

4.7 Telegram Response Testing

The results of testing the telegram response are obtained by collecting data on the reset of detected face objects that try to access the fence, and to find out how fast the tool responds when sending photos to Telegram. The system provides a message in the form of an image of the face detection results. The difference between homeowners will be given the message 'Detected and the fence is open' while other people will see the message 'Detected an intruder and the door is locked'. The following is a table of results from testing the system's response to the input given.

Table 5. Telegram Response testing

Testing	**Description sent and time (seconds)**	
	Sent successfully / not	Notification Response Time
Ega	Successful	8 second
Ayu	Successful	5 second
Hikma	Successful	8 second

Based on the results of data collection that has been carried out, the average data transmission time can be measured with Equation 2.

$$\text{Average response time} = \frac{\Sigma response\ \ time}{number\ \ of\ \ samples} \quad [2]$$

$$\text{Average response time} = \frac{8+5+8}{3}$$

$$\text{Average response time} = 7 \ \ Second$$

Data from the test results of sending notifications of images detected by the camera sensor. Testing was carried out 3 times for sending time unit image notifications in seconds in each test. The resulting test of the 3 data has an average speed of sending image notifications to Telegram for 7 seconds. This is influenced by the speed of the internet network used.

5. Conclusions

This research is designed in the form of a minimalist fence prototype. The fence is made to function properly, as the purpose of this research was carried out. The result is that the system successfully opens and closes the fence automatically when detecting the face of the homeowner. This researcher has conducted tests for accurate object detection, distance detection, and overall system prototype performance. This researcher produces an object detection accuracy value of 86% with an average telegram response of 7 seconds. A well-designed facial recognition system can provide a high level of accuracy in identifying residents and guests, thereby reducing the risk of unauthorised access.

Acknowledgments: Thanks to the entire team who helped in the process of working on this research. Hopefully, research in the fields of AI, Machine Learning, Image Processing, and the like can be explored more deeply in the future and be able to compete in the industrial world.

Author contributions: The authors are responsible for building Conceptualization, Methodology, analysis, investigation: **Ega Nurwani Faisal, Jumadi M Parenreng, Muliadi**, data curation, writing—original draft preparation, writing—review and editing, visualization: **Ega Nurwani Faisal, Jumadi M Parenreng, Muliadi,** supervision of project administration, funding acquisition: **Ega Nurwani Faisal, Jumadi M Parenreng, Muliadi,** and have read and agreed to the published version of the manuscript.

Funding: The study was conducted without any financial support from external sources.

Availability of data and Materials: All data are available from the authors.

Conflicts of Interest: The authors declare no conflict of interest.
Additional Information: No Additional Information from the authors.

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