

Design Of Automatic Home Door Security Using Face Recognition with A Convolutional Neural Network (CNN) Model

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Abstract

In Indonesia, the majority of residences continue to utilise traditional keys for door access. Keys are essential for house security; nonetheless, numerous criminals can circumvent this protection. A viable option to avert similar tragedies is to substitute the door security system with facial recognition technology. This security system employs CNN programming and an Arduino application. It utilises an ESP32 to autonomously open and close the door and engage a buzzer upon detecting a potential intruder. This research examines facial recognition technology utilised for door unlocking. The device exhibits a success rate of 71.4%, evaluated under various situations across five trials for each object.

Further upgrades to the gadget and system developed from this research can be achieved by incorporating more features and tools for detecting low light levels in a room. Furthermore, the system might be engineered to detect from considerable distances, such as many kilometres away.

Keywords: *Face Recognition, ESP32, CNN, Arduino*

Introduction

Technological and communicative advancements have led to an increasing demand for expedited and more efficient solutions within society. These improvements motivate individuals to persist in researching and uncovering methods to streamline daily tasks, including the exploration of technology in the realm of security.

Security denotes a state devoid of danger or threats. It is an essential component of every information system (Nabila et al., 2022; Tribuana et al., 2024). Enhancing security systems can avert criminal cases. A facial detection system for door security has been created utilising the Convolutional Neural Network (CNN) methodology. The Convolutional Neural Network, referred to in Indonesian as Jaringan Saraf Konvolusional, is a technique for advancing Multi-Layer Perceptron (MLP) machine learning to analyse two-dimensional data. Convolutional Neural Networks (CNNs) are categorised as Deep Neural Networks due to their numerous layers. Biometric systems are fast advancing, primarily employing facial traits for detection via face recognition (Rahim et al., 2023).

Face Recognition

The implementation of biometric technology is advancing swiftly. Biometric techniques typically employ facial characteristics for identification via facial recognition (Mishra et al., 2020; Radzi et al., 2020). Face recognition is a technology that utilizes computer systems to identify faces through a camera visually. The process of facial recognition parallels human visual perception. The facial detection gadget operates by correlating facial forms, textures, and other distinctive traits specific to each individual. The visual data analysed by the computer comprises pixels or picture parts. The visual display generally manifests in monochrome, grayscale, and actual colour—numerous factors affecting visual output include brightness, contrast, contour, colour, shape, and texture.

Convolutional Neural Network (CNN)

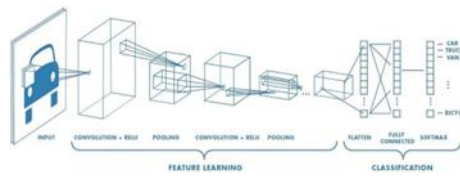


Figure 1. CNN algorithm architecture

A Convolutional Neural Network (CNN) is an algorithm classified as part of deep learning. Convolutional Neural Networks (CNNs) are frequently employed for object recognition through detection and segmentation processes. Their architecture has a significant influence on the efficacy of CNNs in detection (Mun & Lee, 2022; Phawinee et al., 2021).

A CNN comprises an input layer, an output layer, and several hidden layers. The concealed layers of a CNN consist of convolutional layers, pooling layers, fully connected layers, and normalisation layers (ReLU). Further layers may be included in the CNN to develop a more intricate model. (Rahim et al., 2022) This exemplifies a CNN architecture.

Arduino Software (IDE)

The Arduino Software (IDE) is a programming application that comprises a code editor, a text console, a message area, functioning buttons, and several additional menus. It facilitates access to the Arduino, enabling users to upload desired programmes and interact with the gadget. (Febriantono et al., 2023)



Figure 2. Arduino

The author aims to develop an automated and efficient house door lock system utilising advanced technologies, including Face Recognition through the CNN model.

Research Method

The research technique entailed the creation of a door security system that replaces conventional keys with facial recognition technology. The system incorporates Convolutional Neural Network (CNN) programming with an Arduino application. An ESP32 microcontroller is used to automate the door's opening and closing mechanism, while activating a buzzer upon detecting a potential intruder. The research examines the efficacy of facial recognition technology for door unlocking, conducting five trials for each object under diverse settings. The device attained a success rate of 71.4%, demonstrating its reliability in practical applications.

The research recommends integrating supplementary features and tools to augment performance in low-light conditions. This entails enhancing capabilities for remote detection, allowing the system to identify faces from several kilometres away. These developments will enhance the security system's versatility and mitigate obstacles presented by fluctuating illumination circumstances, consequently augmenting overall security efficacy.

Result and Discussion

Analysis and Design

Ongoing Analysis

The current examination involves deconstructing the existing system to identify and assess emerging issues. The ongoing analysis encompasses:



Figure 3. Analysis of the running system

System Overview

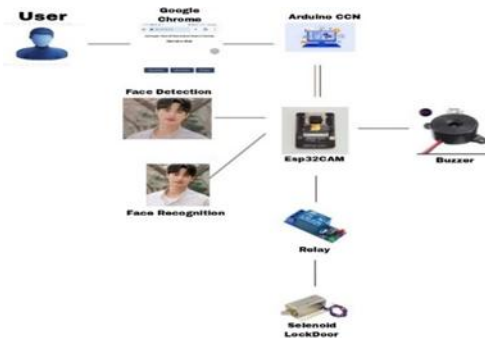


Figure 4. System Overview

Use Case Diagram Design

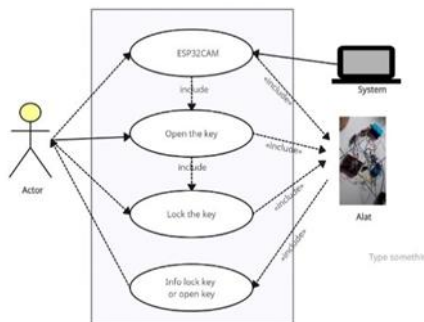


Figure 5. Use Case Diagram Design

Use Case Narrative

Use Case	Smart door lock	
Actor	Pengguna, tamu, pengasuh rumah tangga, pencuri	
Precondition	Esp32-cam on	
Postcondition	Sistem sudah tersambung dengan alat	
Main Flow of Event		
Action Actor		System Response
1	Menyalakan stop kontak	2 Menampilkan alat menyala
3	Menzisi mendekatkan wajah ke Esp32-Cam	Mendeteksi wajah sudah terdaftar atau tidak
5	Buzzer berbunyi	a. Jika salah, maka buzzer akan berbunyi
6	Solenoid	b. Jika benar, maka solenoid akan terbuka

Figure 6. Use Case Narrative

Activity Diagram

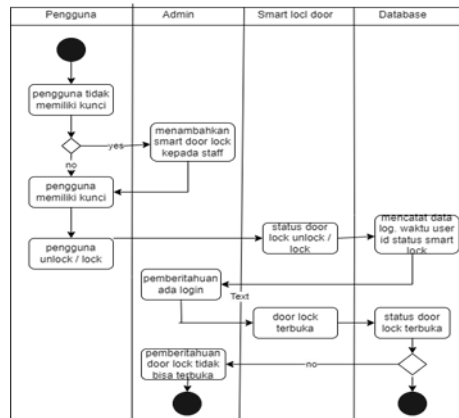


Figure 7. Activity Diagram

Sequence Diagram

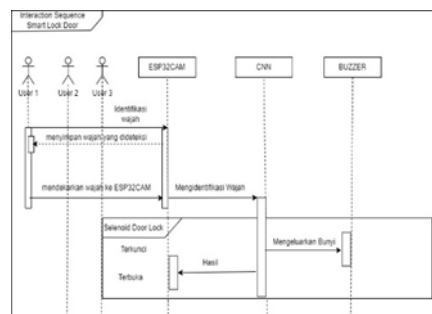


Figure 8. Sequence Diagram

Prototyping Design

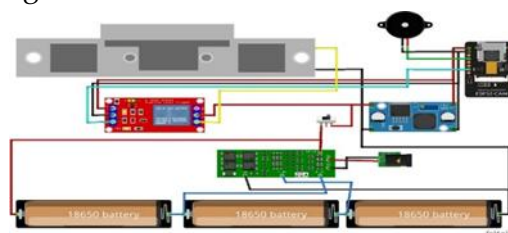


Figure 9. Prototyping Design

Description:

1. The ESP32-Cam is used to process the created program and to operate the existing sensors.
2. The step-down transformer is used as a communication bridge to send and receive power between devices.

3. The switch is used as an on-off button for the device to indicate or notify activity on the device while it is running.
4. The buzzer is used to indicate whether or not a face has been registered on the sensor.
5. The relay module is used to break the electrical circuit and connect the electrical current.
6. The solenoid is used as a door lock.
7. An 18650 Ultrafire battery can provide backup power.

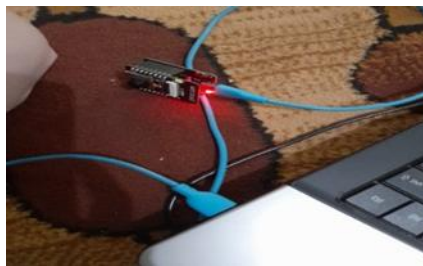


Figure 10. ESP32-Cam Connected to Laptop

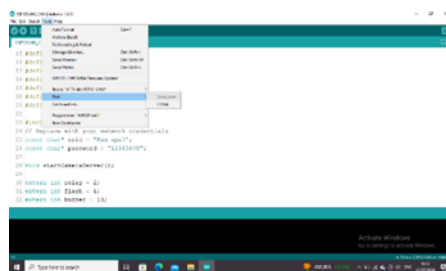


Figure 11. Enter the Program



Figure 12. ESP32-Cam is Connected To The Device

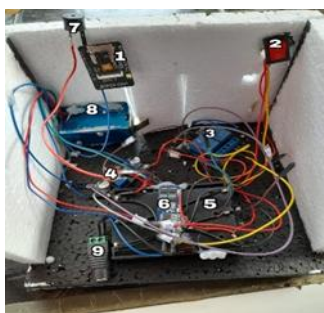


Figure 13. The Entire Set Of Tools

1. Undetected and unregistered facial data

If the system and device do not detect facial data, the buzzer will sound, and the solenoid will not automatically open. The results are as follows:

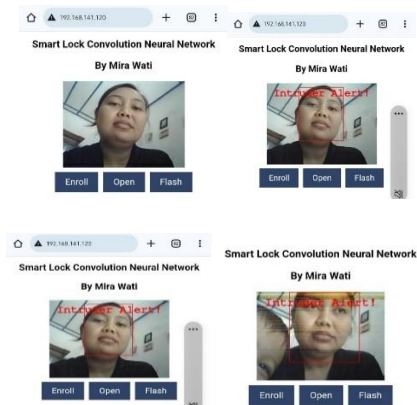


Figure 14. Undetected and unregistered facial data

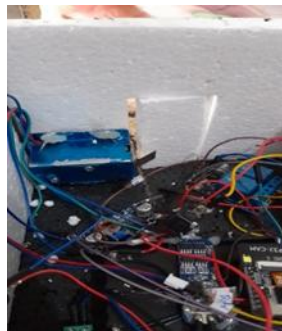
Table 1. Results of testing unregistered facial samples

No	Sempel wajah	Status	System	Doorlock	Buzzer	Ket
	Sempel id 0					
1	Sempel wajah 1	Terdaftar	Tidak di kenali	Off	On	Tidak sesuai
2	Sempel wajah 2	Terdaftar	Tidak dikenali	Off	On	Tidak sesuai
3	Sempel wajah 3	Terdaftar	Tidak di kenali	Off	On	Tidak berhasil
4	Sempel wajah 4	Terdaftar	Tidak dikenali	Off	On	Tidak sesuai

The table above represents the initial assessment of the comprehensive facial data tool, with the facial recognition accuracy for each test indicated by the formula below:

$$\begin{aligned}
 & \text{Hasil berhasil} \\
 \text{Akurasi deteksi wajah} &= \frac{\text{Jumlah pengujian}}{\text{Jumlah pengujian}} \times 100\% \\
 \text{Akurasi pengujian 1} &= \frac{0}{4} \times 100\% \\
 &= 0\%
 \end{aligned}$$

The facial sample data indicates that the face is undetectable and unregistered; hence, the solenoid will not activate, the buzzer will ring automatically, and the door will stay secured.



2. Detected and registered facial data

The system and gadget will automatically activate the solenoid upon detecting and registering facial data, and the buzzer will remain silent. The outcomes are as follows:

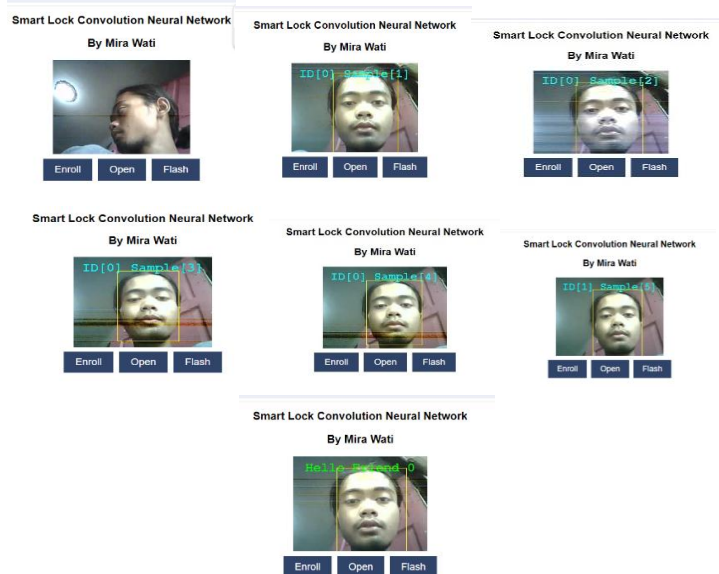


Figure 15. Detected and registered facial data

Table 2. Results of testing unregistered facial samples

No	Sempel wajah	Status	System	Doorlock	Buzzer	Ket
	Sempel id 0					
1	Sempel wajah 1	Sedang mendaftar	Dikenali	Proses	Off	Sesuai
2	Sempel wajah 2	Sedang mendaftar	Dikenali	Proses	Off	Sesuai
3	Sempel wajah 3	Sedang mendaftar	Dikenali	Proses	Off	Sesuai
4	Sempel wajah 4	Sedang mendaftar	Dikenali	Proses	Off	Sesuai
5	Sempel wajah 5	Sedang Terdaftar	Dikenali	Proses	Off	Berhasil
6	Sempel wajah 4	Sedang mendaftar	Dikenali	Proses	Off	Sesuai
7	Sempel wajah 5	Terdaftar	Dikenali	Terbuka	Off	Berhasil

The table above represents the initial assessment of the comprehensive facial data tool, with the facial recognition accuracy for each test indicated by the formula below:

$$\text{Akurasi deteksi wajah} = \frac{\text{Hasil berhasil}}{\text{Jumlah pengujian}} \times 100\%$$
$$\text{Akurasi pengujian 2} = \frac{5}{7} \times 100\%$$
$$= 71,4\%$$

The facial sample data indicates that facial detection and registration are successful; thus, the solenoid will activate, the buzzer will remain silent, and the door will open automatically.



Coclusion

This research concludes that the automatic door security system employing facial recognition technology with a Convolutional Neural Network (CNN) model is successful. This unique design addresses prevalent issues faced by landowners, particularly the challenge of vacating the premises when sure occupants have not yet arrived. This technique eliminates the need to hide the house key in locations such as vents, offering a safer and more convenient method for home access.

Additionally, the device operates as a digital key, augmenting home security with contemporary facial recognition sensors. Several proposals

have been offered to future researchers to enhance this foundation. This encompasses enhancing the program and device to align with technical progress, establishing a system for remote identification capabilities, and ensuring that the system can still identify registered faces even when the device is powered down, thereby obviating the need for re-registration.

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