Automatic Door Lock Based on Knock Pattern and Face Detection

Danang Fariz Zulhaq[1,a)], Iman Fahruzi[2,b)]

[1,2]*Department of Electrical Engineering, Politeknik Negeri Batam, Kota Batam, Indonesia*

[b)]Corresponding author: imanfahruzi@gmail.com

Abstract. Residential burglaries are prevalent offenses, frequently occurring during the absence of homeowners. These offenses generally entail breaching doors or windows. An innovative home security system is important to resolve this issue. This research seeks to create an automated door locking mechanism utilizing knock patterns and facial recognition to improve residential security. The system incorporates a piezoelectric sensor for detecting knock patterns and an ESP32-Cam for facial recognition. The study methodology entails the development and evaluation of a system that integrates two primary components, guaranteeing that the door unlocks solely upon the recognition of both an accurate knock pattern and a registered facial image. The system's accuracy was assessed under varying lighting situations and distances to determine its efficacy. The results indicate that the face detection system operates effectively under optimal lighting settings, and the knock pattern system activates the door lock mechanism when the knock intervals correspond to the pre-registered pattern. Nonetheless, the system encounters difficulties in recognizing faces in low-light conditions. The door lock is secure, as it will only unlock when both the appropriate facial recognition and knock pattern criteria are satisfied, thus improving security relative to conventional locks. This dual-layer security strategy mitigates the dangers inherent in traditional systems, such as keys or PINs, which are susceptible to theft or circumvention. The proposed technology significantly enhances home security, presenting a more secure and user-friendly alternative to current options. Future enhancements may concentrate on augmenting the precision of facial detection in low-light environments and refining the system for wider practical applications.

Keywords: Piezoelectric Sensor, ESP32-Cam, Solenoid Door Lock.

INTRODUCTION

The majority of the day's tasks are carried out externally. This occurs in all major urban areas. Consequently, it has been established that tenants of numerous vacant homes are required to vacate during business hours; this is particularly applicable during holiday periods, including Eid, Christmas, and New Year's. Vacant properties are often perceived as accessible targets for thieves, particularly in the absence of adequate security measures [1]. Burglary is one of the most prevalent offenses committed. These offenses are generally perpetrated by gaining unauthorized access through the front door, back door, or windows while the owner is absent. Due to the frequency of these instances, the installation of a home security system is essential. It is crucial to consider attention [2]. To enhance door security, one can implement a security system by substituting traditional mechanical locks with technologically advanced electronic locks [3]. The current technology consists primarily of automatic door locks that utilize radio frequency cards. automated door locks with Radio Frequency Identification (RFID) cards and passwords [4]. As previously stated, the realm of security has yet to determine which smart door locks are optimal and most effective, as each existing product continues to exhibit inherent deficiencies [5]. Consequently, an advanced automatic door lock system is essential to safeguard the residence from criminal activities. protecting the residence from criminal activities.

METHODS

Hardware And Software Systems

The primary objective of this study is to enhance the security of the door locking mechanism. The proposed system's hardware and software specifications are presented in [11]. This section will examine the block diagram along with the operational principles of each component within the diagram. The block diagram includes a design for the activator block (voltage source), an input block design, a process block design, and an output block design (output) [12].

TABLE 1. Hardware and software requirement

Category	Component	Function
Hardware	ESP 32 Cam	As a suitable face detector
	Arduino Atmega 2560 Pro	As a data processor
	Relay	As a voltage retainer so that the solenoid works according to the direction or program
	Solenoid 12 V	As a conditioned door lock
	Buzzer	As an indicator of a tool
	Light Emitting Diode	As an indicator of a tool
	Step Down Regulator	As a voltage reducer or safety
	Battery 12V	As the main source
	Module Charge (TP4056)	As a charger for the battery
	Piezo Sensor	As a vibration detector
	Button	As a new knock pattern maker
Software	Arduino IDE	To write and send programs to hardware
	Web Server	To store face data on ESP 32 CAM

Table 1 is shown the device will operate using a system that integrates the ESP32 CAM with the Arduino Atmega 2560 Pro as the microcontroller. The system previously saved facial data in the internal database of the ESP32 CAM, while the Arduino Atmega 2560 Pro recorded the requisite data via piezo sensors. the utilization of these two methods to deliver security that surpasses traditional locks.

E-ISSN:2798-4664

Automatic Door Security Systems

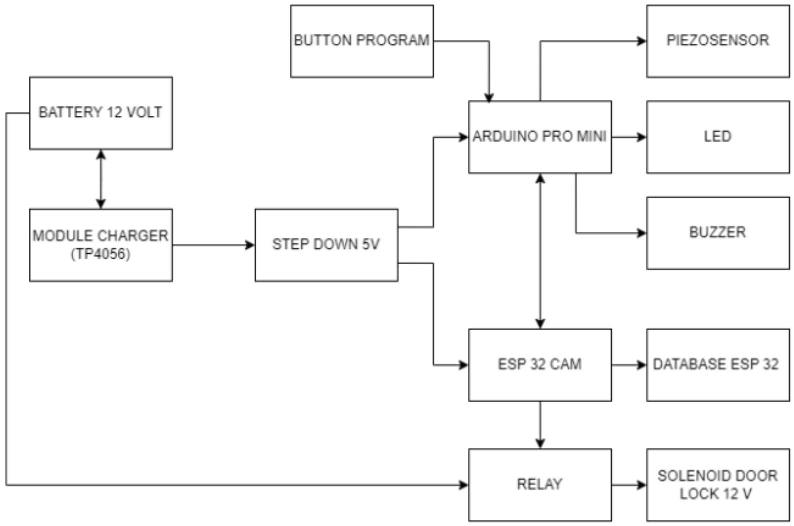

FIGURE 1. Block diagram of the proposed systems.

Fig. 1 illustrates the block diagram of the automatic door security system utilizing a knock pattern and facial recognition. As depicted, the components of the system are interconnected. By considering user-friendliness, the researcher meticulously develops the concept, including the incorporation of a 12-volt battery as a backup power source when the primary supply is unavailable. The selection of components is also taken into account to decrease usage costs.

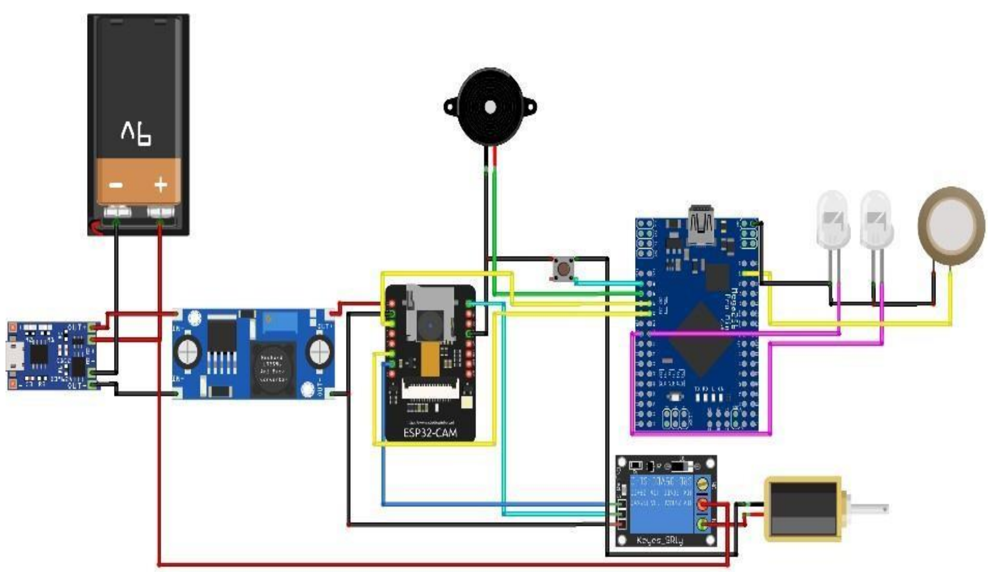

FIGURE 2. Hardware circuit connection of the porposed systems.

Fig. 2 illustrates the hardware circuit utilized in this study. The circuit initiates with the primary power source, specifically a 12-volt battery linked to a charging module for recharging purposes. Current will travel from a battery to a step-down transformer and then to a relay. What is the necessity of a stepdown? A microcontroller can accept a maximum voltage of 5 volts. Subsequently, we possess two microcontrollers: the ESP32 CAM, utilized for facial detection, and the Arduino Atmega 2560 Pro, designated as the microcontroller for a piezo sensor or knock pattern sensor. Additionally, there are various indicators, including a buzzer and LED, to signal whether the user input is accurate or erroneous. The push button is utilized to reset or re-enter input into a microcontroller without necessitating code reprogramming. This tool functions only when both systems receive accurate input; incorrect input will prevent the door lock or solenoid door lock from operating, as the relay will not receive signals from the ESP 32 CAM and Arduino Atmega 2560 Pro, which are integrated to form a cohesive security system.

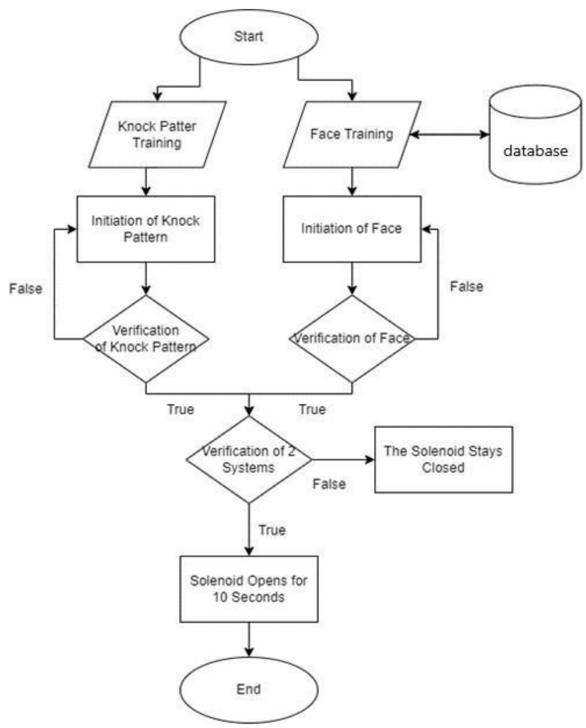

FIGURE 3. Flowchart of the proposed systems.

Fig. 3 Shows a flowchart, which is a step-by-step approach followed in writing an automatic door security program, which allows the execution of a command desired by the author. The program design encompasses four stages: the creation of a flowchart, the utilization of Arduino IDE software, and the design of tools and materials for the circuit. Every phase in the system design necessitates foresight and precision, as the initial design will dictate the outcome of the tool-making process. The preliminary design will dictate the conclusion of the design phase in the tool-making process. Should the design phase succeed and adhere to the established criteria, the resultant tool will function as anticipated [15].

RESULTS AND DISCUSSION

This section presents the results of a tool featuring an automatic door lock system that employs facial detection and knock patterns. The evaluation involves testing both the face detection system and the knock pattern system. The evaluation will assess the precision of facial recognition and the reliability of knock patterns.

IMPLEMENTATION DESIGN

The tool's architecture comprises multiple components integrated on a single hollow PCB board, utilizing two microcontrollers: the Arduino Atmega 2560 Pro and the ESP 32 Cam. The required voltage sources for this device are 5 volts for the microcontroller and 12 volts for the solenoid door lock, along with other components including LEDs, piezoelectric sensors, buzzers, relays, and buttons, which need a 5-volt input. The results demonstrate that the system operates according to the initial concept, utilizing two security mechanisms to unlock a solenoid door lock. This is an image of the completed tool:

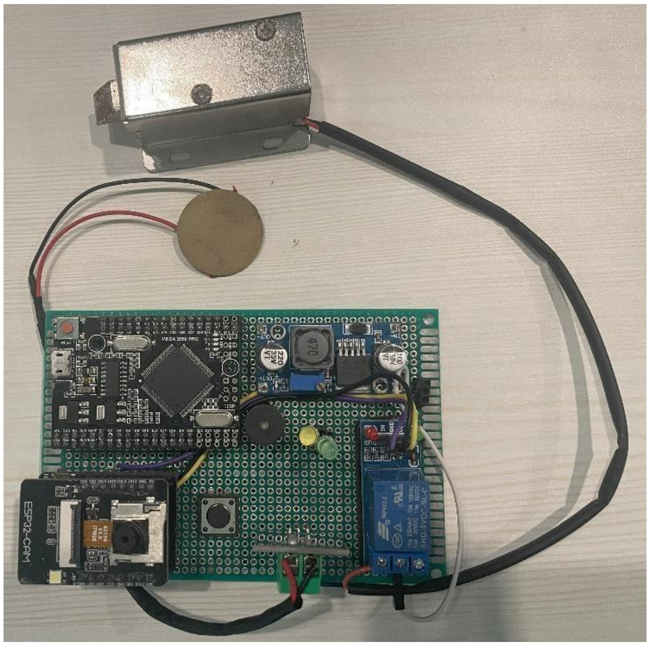

FIGURE 4. Overall Implementation Design

Fig. 4 illustrates a tool composed of multiple integrated components. The automatic door lock system will function if two validated systems are in place: facial recognition and pre-registered knock patterns. If the validated knock pattern is accurate, LED 1 will illuminate; if face detection is accurate, LED 2 will illuminate. If both LEDs are illuminated concurrently, the solenoid will activate for 5 seconds, as per the prior design.

FACE DETECTION SYSTEMS USING WEB-BASE APPLICATION

The initial testing procedure involves evaluating the functionality of the face detection system. Testing was conducted by interfacing the tool with a laptop or computer capable of uploading programs to the ESP 32 – CAM controller. Subsequently, there will be a web platform capable of verifying whether our facial features are recorded in the system and also enabling the registration of our faces within the system over the web. Prior to commencing tool testing, initialization is performed using a database of faces saved on the system [2]. The subsequent stages outline the procedure to activate the facial detection system:

1. Launch the Arduino IDE application.
2. Establish a connection between the ESP32 Cam and a laptop or PC.
3. Ensure that the software has been successfully uploaded to the ESP32 Cam and verify that the connections to the program and the PC/Laptop are identical.
4. Access the serial monitor feature in the Arduino IDE application.
5. Activate the reset button on the ESP32 Cam to exhibit the IP address on the serial monitor.
6. If the IP address is displayed, copy it and paste it onto the web page.
7. Subsequently, the website will display a page similar to the following.

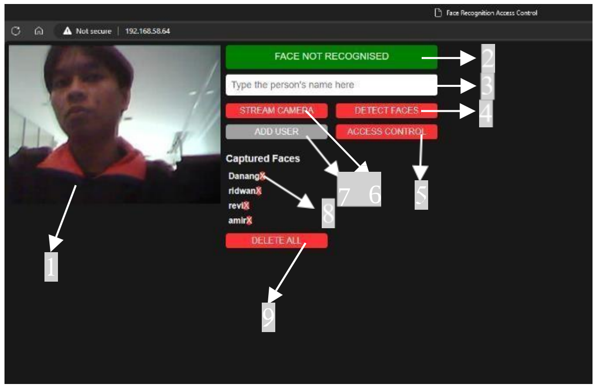

FIGURE 5. Simulation Web View

The web page displays many elements, as illustrated in Fig 5. The subsequent delineates the function of each element:

1. **Face display**: This feature serves as the primary component that shows the face of the ESP 32 Cam.
2. **Indicator Column**: This section serves as a measure of success or failure in detecting a face.
3. **Name Input**: This function is utilized to input or register the name of the individual who will be enrolled in the system.
4. **Detect Faces Column**: This section serves as test material for facial detection.
5. **Access Control Column**: This portion serves as the ultimate control, ensuring the system is incorporated into the microcontroller or capable of awaiting other signals for the tool's operation.
6. **Stream Camera Column**: This segment is exclusively utilized for live video streaming.
7. **Add User Column**: This section of the add user column is applicable if column 3 has been populated concurrently with the function name alongside the name and facial input.
8. **Registered Name**: This registered name is a database entry that can be removed by clicking the X button adjacent to the name.
9. **Delete Column**: This function is utilized to eliminate the complete registered database. This web page is accessible when the device or ESP32 camera is powered on, the appropriate program has been uploaded, and both the ESP32 camera and the laptop/PC are connected to the same Wi-Fi network, as each device will have a distinct IP address.

FACE DETECTION RESULTS

Commencing with the analysis of system requirements, followed by the collection of data through the examination of information and theories pertinent to door security systems. Analyzing facts and theories pertinent to door security systems employing Face Recognition and ESP32Cam with contemporary technology. This will ultimately serve as supporting material in the design and fabrication of a prototype tool for a face recognition-based home entrance security system [10]. This accuracy assessment was conducted with six distinct facial objects that were pre-registered in the internal storage system of the ESP 32 Cam, while one face was unregistered as a trial. The accuracy assessment involves measuring ambient light and the distance from the camera to the subject's face, utilizing the Lux Light Meter application on a smartphone for light intensity measurement and a 60-centimeter ruler for distance measurement. This test evaluates the room's illumination and distance to determine the ideal operational parameters of the instrument, ensuring that daily usage does not encounter systemic issues. Table 2 presents the accuracy.

TABLE 2. Face Detection Results

Registered Face	Ambient Light	Distance 30 CM	Distance 60 CM
Danang	125lx	Undetectable	Undetectable
	180lx	Detected	Detected
Ridwan	130lx	Detected	Undetectable
	183lx	Detected	Detected
Revi	136lx	Detected	Undetectable
	183lx	Detected	Detected
Amir	136lx	Detected	Undetectable
	187lx	Detected	Detected
Rejak	106lx	Undetectable	Undetectable
	140lx	Detected	Detected
Fergian	150lx	Detected	Detected
	200lx	Detected	Detected
Galang (No Registered)	-	Undetectable	Undetectable

Based on the test findings in Table 2, the author finds that the face detection outcomes of this system are notably successful. Testing on six registered faces yielded accurate results; however, when illumination falls below 140 lx, the system struggles to detect faces at a distance of 60 cm, while detection remains effective at 30 cm. If the light level drops below 130 lx, the ESP32 camera fails to detect faces at both 30 cm and 60 cm distances. Furthermore, in this trial, the unregistered face and ESP 32 failed to detect any results. This paper presents the results of face detection tests conducted with the ESP32 Cam on the web server, along with the ambient light values in the room.

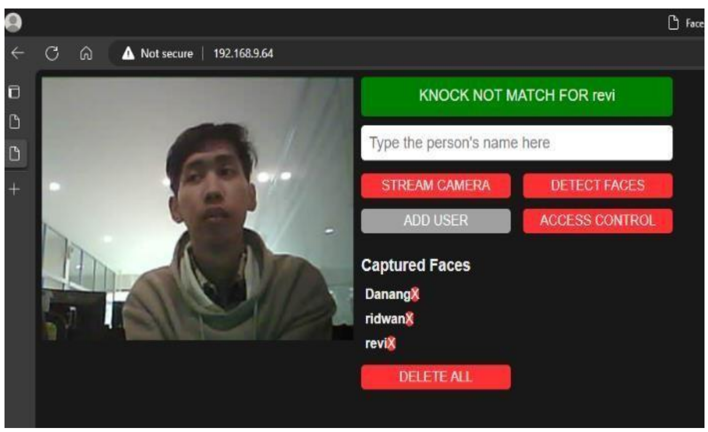

FIGURE 6. Face Detection on web server

Fig. 6. The documentation above is face detection on a web server that has enough lighting and distance to detect the face.

FIGURE 7. Revi room light value in lux light meter application

Fig. 7. The picture above is the room lighting value measured using the lux light meter application which was tested simultaneously with Figure 6.

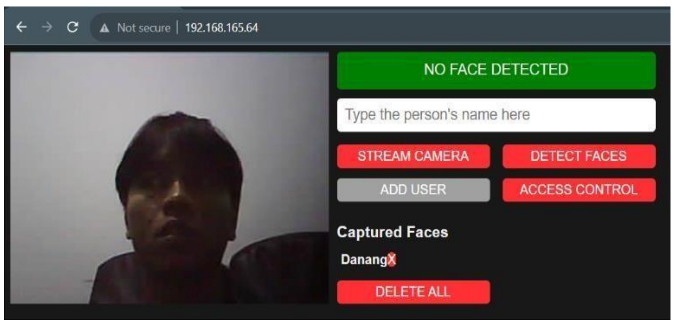

FIGURE 8. Danang face object on web server

Fig. 8. The documentation above is face detection on a web server that has insufficient lighting and sufficient distance to detect the face.

FIGURE 9. Danang room light in lux light meter application

The images of the test results in figures 4, 5, 6, and 7 illustrate the discrepancies outlined in table 2 prepared by the author. Figure 4 displays the registered face (Revi) at a distance of 60 cm, while Figure 5 indicates the room light value when the Revi face is accessed on the system. This information is available on the web server in the green column, stating "KNOCK NOT MATCH FOR Revi," signifying that the face has been detected but is awaiting the input of the tap pattern. A comparison is also made between Fig 4 and Fig 6. In Figure 6, the registered face (Danang) with a room illumination level of 125 lx corresponds to Figure 7, where the green column indicates "NO FACE DETECTED," signifying that the system is unable to detect Danang's face in low light conditions, even at a distance of 30 cm.

KNOCK PATTERN RESULTS

The precision of the knock pattern utilizing piezoelectric technology is assessed with a stopwatch, which serves as an effective assessment of the interval between knocks and the piezoelectric sensor [8]. Should the interval value align with the program's criteria, the program will activate the LED for 10 seconds and engage the solenoid; conversely, if the interval value does not conform to the program's requirements, the LED will only blink and the solenoid will remain inactive. The subsequent authors present a table detailing the interval test results of the piezo sensor.

TABLE 3. Interval value data of knock pattern using piezoelectric sensor

Interval	0 - 1 *ms	1 - 2 *ms	2 - 3 *ms	3 - 4 *ms	Results
Initial Value	710	760	780	780	Registered
Interval Value 1	580	660	760	750	Accepted
Interval Value 2	730	570	760	760	Rejected
Interval Value 3	860	830	810	910	Accepted
Interval Value 4	640	600	680	760	Rejected
Interval Value 5	700	650	800	850	Accepted
Interval Value 6	630	590	830	800	Rejected

Table 3 presents data compiled by the author, followed by an explanation of the table's contents.

1. **Initial value**: The reference knock input utilized for automatic door locks employing knock patterns.
2. **Interval value tests 1, 3, and 5**: In the interval test, this section yields identical results; specifically, the microcontroller identifies the same knock pattern between the initial interval value and the interval values of 1, 3, and 5, with the most significant comparison occurring in the third interval value test within the range of (0-1), which is 150 ms.
3. **Interval values 2, 4, and 6**: The test intervals in this section yield identical results, indicating that the microcontroller neither detects nor accepts the provided knock pattern, as demonstrated by the accompanying comparison. The rejected value is nearest to the initial value of 160 ms at the 4th interval of the beat pattern (1-2), while the most distant comparison value is at the 2nd interval of the same beat pattern, which is 190 ms. The analysis of the piezosensor data indicates that the interval's maximum and minimum values are 150 ms; if this threshold is beyond, the tone of the knock pattern alters, prompting the microcontroller to determine that the beat pattern is incorrect.

CONCLUSIONS

The automated locking mechanism, reliant on knock patterns and facial recognition, has functioned flawlessly in accordance with the author's specifications. The lock will engage only when both criteria are met; if only one is satisfied, the automatic lock will remain secure. This tool exhibits robust security, as access to both systems necessitates a database in which 12 F. Author and S. Author must be pre-registered prior to usage. Consequently, no one cannot unlock the door arbitrarily, unlike with ordinary keys. However, the tools developed by the author require significant enhancements from several perspectives to facilitate user accessibility.

REFERENCES

1. Masykuroh, K., Syifa, F. T., Setiyanto, G. R., Ramadhani, A. D., Kurnianto, D., & Iryani, N. (2021, July). Prototype smart door lock by using wireless network based on arduino uno. In 2021 IEEE International Conference on Communication, Net- works and Satellite (COMNETSAT) (pp. 342-347). IEEE.
2. Muwardi, R., & Adisaputro, R. R. (2021). Design Sistem Keamanan Pintu Menggunakan Face Detection. Jurnal Teknologi Elektro, 12(3), 120- 128.
3. Iman, N., Sabna, E., & Fonda, H. (2021). Sistem Pintu Otomatis Menggunakan E- KTP Berbasis Internet of Things (IoT) pada Kamar Hotel. SATESI: Jurnal Sains Teknologi dan Sistem Informasi, 1(2), 85-91.
4. Ahmad, A., & Ikhlas, M. (2020). Sistem Membuka Pintu Dengan Ketukan Bernada Menggunakan Mikrokontroler Atmega328. J-SAKTI (Jurnal Sains Komputer dan Informatika), 4(2), 368-378
5. Aswini, D., Rohindh, R., Ragavendhara, K. M., & Mridula, C. S. (2021, October). Smart Door Locking System. In 2021 International Conference on Advancements in Electrical, Electronics, Communication, Computing and Automation (ICAECA) (pp. 1-5). IEEE.
6. Salam, A., & Bhaskoro, S. B. (2021). Sistem Keamanan Cerdas pada Kunci Pintu Otomatis menggunakan Kode QR. Cybernatics, 5(01), 1-11.
7. Adam, M. (2019, October). Pemanfaat Mikrokontroller Atmega8 Sebagai Pengaman Pintu Menggunakan Metode Sidik Jari (Fingerprint). In Prosiding Seminar Nasional Kewirausahaan (Vol. 1, No. 1, pp. 279- 289).
8. Fitriyani, Y. (2022). Security Door System Using Knock Sensor Based On Arduino Uno. Jurnal Info Sains: Informatika dan Sains, 12(1), 13-17.
9. Shanthini, M., Vidya, G., & Arun, R. (2020, August). IoT enhanced smart door lock- ing system. In 2020 Third International Conference on Smart Systems and Inventive Technology (ICSSIT) (pp. 92-96). IEEE.
10. Indriawan, M. H., Shabrina, F., & Mardhiyya, A. (2022). SISTEM KEAMANAN PINTU RUMAH BERBASIS FACE RECOGNITION. JUPITER: Jurnal Penerapan Ilmu-ilmu Komputer, 8(2), 34-42..
11. Basit, A., Putra, A. S. B., Revira, G. A., & Widia, R. N. (2022). Smart Door Lock Berbasis QR Code. Smart Comp: Jurnalnya Orang Pintar Komputer, 11(1), 5-8.
12. Gultom, D., & Susanto, M. F. (2020, September). Studi Aplikasi Smartlock Pada Pintu Rumah Dengan Arduino Berbasis Iot Dengan Sensor Suara. In Prosiding In- dustrial Research Workshop and National Seminar (Vol. 11, No. 1, pp. 239-245).
13. Arafah, M., Iskandar, A., Maslihatin, T., Ramlah, R., & Rahim, A. (2023, February). Sistem Penguncian Cerdas Pada Pintu Berbasis Face Recognition. In Seminar Nasional Teknik Elektro dan Informatika (SNTEI) (Vol. 8, No. 1, pp. 158-162)