ISSN:2723-1283, Volume 7, Mei 2026

Implementation of Smart Lock with Face Recognition Module and Vibration Sensor as an Automatic Door Security System

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Abstract: *As Internet of Things (IoT) technology develops, the demand for more sophisticated and automated security systems is also increasing. This research aims to design and implement a Smart Lock system based on facial recognition integrated with a vibration sensor to enhance automatic door security. The system uses an ESP32-CAM as the main microcontroller, a Solenoid Door Lock as the locking actuator, and an SW-420 vibration sensor to detect physical disturbances. The method used in this study is system engineering experimentation, starting from hardware design, module programming, and functional system testing. Data was collected to measure the accuracy of facial recognition, the sensitivity of the vibration sensor, and the response of the automatic door lock actuator. Test results show that the system can detect authorized user faces with up to 90% accuracy at an optimal distance of 50–80 cm. The vibration sensor also quickly responds to disturbances, sending signals to the system to trigger alarms or notifications. The system has been tested in several simulation scenarios and produced stable results.*
Keywords: Smart Lock, Face Recognition, Vibration Sensor, ESP32-CAM, Automatic Security System.

INTRODUCTION

The Internet of Things (IoT) is now widely used to help meet various needs. IoT connects a device to the internet, enabling users to connect and communicate (Salpina et al., 2025). One of the necessary uses of IoT is related to innovative, automatic, and reliable security systems. The implementation of this technology can be seen, for example, in the use of Smart Locks integrated with face recognition and vibration sensors. This system improves door security because only registered users can access it, and it can detect break-in attempts through vibrations (Prakarsa et al., 2023).

Home and building security is a significant concern in today's digital age. The threat of theft and unauthorized access has driven the development of more intelligent, automated security systems. Conventional locking systems, such as manual or PIN locks, have weaknesses. For example, unauthorized parties can easily guess or copy them (Asysyauqi et al., 2025). Smart Lock is a modern solution to these security issues (Putri & Agung, 2025). This technology allows doors to be opened only by users recognized by the system, such as through facial recognition, fingerprint recognition, or RFID. Among these methods, facial recognition offers a high level of convenience and security because it is unique and challenging to forge (Prakoso & Ramadhanti, 2024).

Based on the previous explanations, the design of this smart lock is important to be carried out. The ultimate goal of this research is to create a smart lock system that is responsive and accurate, physically secure, and easy to implement in a home environment. Thus, it can provide sustainable benefits for its users (Assubhi & Rahmadewi, 2024). This research combines two technologies, namely face recognition and vibration sensors, both of which are integrated through the ESP32-CAM microcontroller. The ESP32-CAM can detect faces and process data locally using an internal camera. Based on the authentication results, a solenoid is used as an actuator to lock and unlock the door.

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RESEARCH METHODOLOGY

This study uses an experimental method that aims to test the performance of a system by manipulating independent variables and observing their effects on dependent variables (Poetra et al., 2023). The experiments in this study were conducted to measure the performance of a smart lock system based on facial recognition and vibration sensors as an automatic door security system.

The variables used in this study consist of independent and dependent variables. The independent variables are the facial images captured by the ESP32-CAM camera for authentication, the analog/digital output from the SW-420 sensor when there is vibration on the door, the distance between the user and the Camera when the face is captured (30–100 cm), and the lighting conditions (bright or dim) during facial recognition. The dependent variables are whether the face is recognized (access granted) or rejected (access denied), the time from recognition to door unlocking (in seconds), the door status (open or closed) based on recognition results, and the alarm activation when the sensor detects vibrations.

The research flow for this study is shown in Figure 1 below:

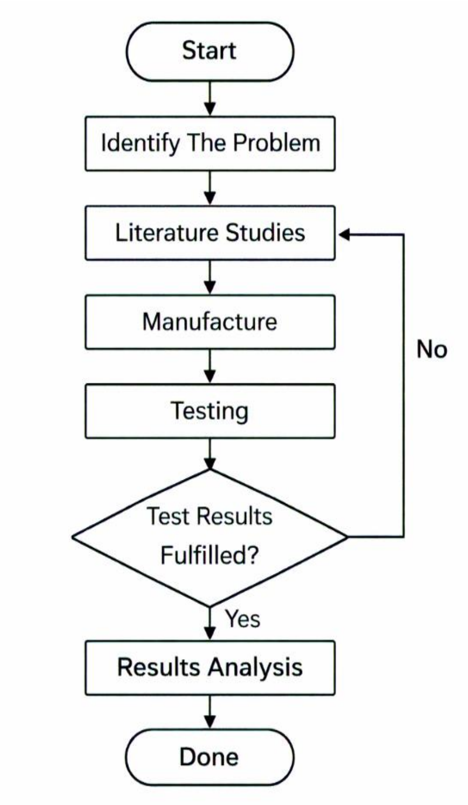

Figure 1. Research Flow

The innovative lock-based automatic door security system begins with an initial activation process. When the system is turned on, all components, including the ESP32-CAM camera, vibration sensor, and solenoid lock, will enter standby mode. At this stage, the system prepares itself to receive input from the user, either in the form of facial images or motion detection at the door. The system also initializes the connection to the network module (if connected to the cloud or notification system) and ensures that the sensors and actuators function normally.

The next step is capturing the user's face image. The ESP32-CAM camera automatically captures the face image when someone stands before the door. The captured image is processed in real time using the face recognition algorithm embedded in the ESP32 program. The system compares the Camera's capture results with the face data stored in the system memory.

After the face matching process is complete, the system evaluates whether the detected face matches one of the registered users' faces. If the face matches, the system proceeds to the next step: opening the door. Conversely, if the face does not match, the system keeps the door locked, and the user is not granted access. In some developments, the system can also record the incident or activate notifications as an additional security measure.

If the user's face is recognized and verified, the ESP32-CAM will automatically signal the solenoid module to unlock the door. At the same time, the system also activates the SW-420 vibration sensor to detect potential physical interference with the door during the door opening process. It is important to ensure security not only during authentication, but also while access is in progress. The vibration sensor acts as an early detection system in case of attempted vandalism or break-ins from outside.

After the authentication process is complete and access is granted, the system returns to standby mode to await the next interaction. This process repeats continuously for each user attempting to access the door. With the combination of biometric verification and physical monitoring through sensors, this smart lock system provides higher security and responsiveness than traditional lock systems. Therefore, the system is very suitable for use in homes, dorm rooms, storage rooms, and facilities with limited access requirements.

Next, the system design was carried out. The system design in this experimental study can be seen in Figure 2 below:

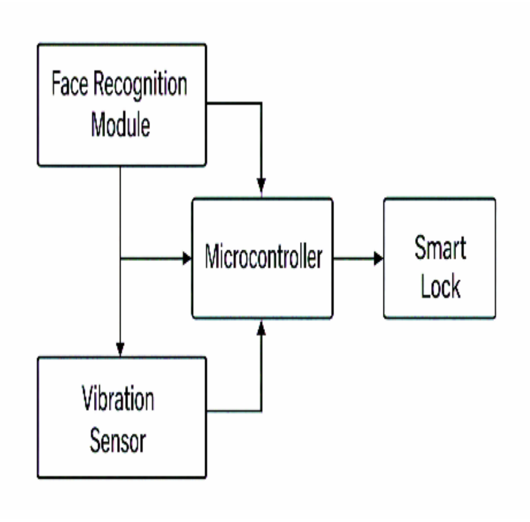

Figure 2. System Workflow Block Diagram

The block diagram in Figure 2 above illustrates the workflow of a smart lock based on facial recognition and vibration sensors. The system has four main components: a facial recognition module, a vibration sensor, a microcontroller, and a smart lock (automatic lock). The flow of information begins when the user approaches the system to be identified by the facial recognition module, which is then further processed by the microcontroller.

The facial recognition module captures and recognizes the user's face. The facial image data captured by the Camera is compared with the stored facial data. This module signals the microcontroller to grant access permission if the face is recognized. This module is the core of the biometric authentication system, providing uniqueness and high security, as only individuals whose faces are registered can open the door.

The vibration sensor functions as an additional security system. This sensor detects unauthorized physical attempts, such as vibrations caused by kicking, prying, or hitting the door. The sensor also sends a signal to the microcontroller as a warning. This sensor adds a layer of protection by enabling the system to detect non-digital threats.

The microcontroller acts as the control center for the entire system. It receives input from the face recognition module and vibration sensor, then makes decisions based on pre-programmed logic. If the face matches, the microcontroller activates the actuator on the smart lock to open the door. Conversely, if the vibration detection indicates a threat, the microcontroller can trigger an alarm or notification system that the user can receive directly.

The smart lock is the final component that receives commands from the microcontroller. If the command is to unlock the door, the solenoid will activate, and the door will open automatically. If not, the door remains locked.

Next, data is collected through observation by monitoring the system's response to facial and vibration inputs, measuring response time with a stopwatch, and documenting the system testing activities. After all these processes are completed, data analysis is conducted. The data analysis activities in this study were performed to analyze facial recognition accuracy, vibration sensor sensitivity, and response time.

RESEARCH RESULTS

Face Recognition Accuracy

After conducting a series of in-depth tests on the Smart Lock system that was designed and implemented, the results of the accuracy of face recognition were obtained. The data on face recognition accuracy can be seen in detail in Table 1 below:

Table 1. Face Recognition Accuracy Results

Distance to Camera (cm)	Lighting	Number of Tests	Face Detected Correctly	Accuracy (%)
30	Terang	10	9	90
50	Terang	10	10	100
70	Terang	10	8	80
50	Redup	10	7	70
70	Redup	10	6	60

Referring to Table 1 above, the results of facial recognition accuracy show that by conducting 10 tests at distances of 30 cm, 50 cm, and 70 cm using bright lighting, the number of faces detected was 9, 10, and 8, resulting in accuracies of 90%, 100%, and

80%. Meanwhile, when testing 10 times at distances of 50 cm and 70 cm under dim lighting, the number of faces detected was 7 and 6, respectively, resulting in 70% and 60% accuracy rates. Thus, the system performs optimally at a distance of 50 cm under bright lighting, achieving an accuracy rate of 100%.

Sensitivity of SW-420 Vibration Sensor

After conducting a series of in-depth tests on the Smart Lock system that has been designed and implemented, the sensitivity of the SW-420 vibration sensor was obtained. The data on the sensitivity of the SW-420 vibration sensor can be seen in detail in Table 2 below:

Table 2. Results of SW-420 Vibration Sensor Sensitivity

Type of Disorder Physical	Vibration Intensity	Sensor Detected	Response Time (seconds)
Light tapping (fingers)	Low	No	-
Medium beat (book)	Currently	Yes	0.7
Hard punch (hand)	High	Yes	0.4
Door shaking (sliding)	High	Yes	0.5
Without interruption	-	No	-

Referring to Table 2, the SW-420 vibration sensor sensitivity results above show that light knocks produce low vibration intensity and are therefore not detected by the sensor. Moderate knocks produce moderate vibration intensity and are detected by the sensor with a response time of 0.7 seconds. Meanwhile, hard knocks and door vibrations produce high vibration intensity and are detected by the sensor with response times of 0.4 and 0.5 seconds.

DISCUSSION

Face Recognition Accuracy

The test results show that the system performs optimally at a distance of 50 cm with bright lighting, where the accuracy rate reaches 100%. This indicates that ESP32-CAM can perform face recognition very well when the user is within the ideal camera focus distance and has sufficient lighting. However, when the distance is reduced to 30 cm, accuracy drops to 90%. This could be due to an unfavorable camera angle or part of the face being obscured by shadows caused by being too close to the lens. At a distance of 70 cm, although still within the Camera's range, accuracy further decreases to 80%. This decline is related to the image resolution decreasing as the face moves further from the lens, making facial features less sharp for processing.

Lighting conditions were also found to affect system performance significantly. In low-light testing, face recognition accuracy dropped dramatically, especially at a distance of 70 cm, which only yielded 60% accuracy. This confirms that adequate lighting is essential in this system, as the ESP32-CAM has limitations in capturing high-quality images in low-light conditions. A feasible solution is to use additional LEDs to enhance the visibility of the user's face. This explanation aligns with research Fahreza et al. (2024), which revealed that different lighting conditions can significantly impact system performance.

Additionally, this testing provides important insights that implementing this system must consider the environment in which it is installed. It is recommended that the device be installed in an area with stable lighting and positioned so that users stand at a distance of 40–60 cm from the Camera. The use of supporting features such as auto-focus or face alignment detection could also be a future solution to improve accuracy under various conditions.

Sensitivity of the SW-420 Vibration Sensor

Test results of the vibration sensor against various forms of physical disturbance on doors. The SW-420 sensor effectively detects vibrations caused by hard blows or shocks, with a speedy response time of approximately 0.4 to 0.5 seconds. This proves that the sensor is highly suitable for early detection against attempted break-ins or forced entry.

For vibrations of moderate intensity, such as those caused by tapping using a book, the SW-420 sensor also performs well, as it can detect such disturbances. Such disturbances are recorded with a sensor response time of 0.7 seconds, which falls into the fast category. Therefore, using the SW-420 sensor for smart locks is highly suitable, as the sensor is highly responsive to moderate to high intensity vibrations. This indicates that the intensity level of disturbances affects the sensitivity of the vibration sensor. The higher the intensity level of disturbances, the higher the sensitivity of the vibration sensor will also be (Zulkarnain et al., 2025).

CONCLUSION

Based on the testing results, the Smart Lock system successfully integrates an ESP32-CAM facial recognition module and an SW-420 vibration sensor to provide a highly responsive, dual-layer automatic door security system. The facial recognition module serves as an effective biometric alternative to conventional keys, achieving high accuracy at an ideal distance of 50 cm with adequate lighting, while the vibration sensor provides real-time early warnings by detecting moderate to high-intensity physical disturbances in under 0.5 seconds. Although effectively implemented for homes, dormitories, or private spaces, the system's reliance on specific lighting and distance conditions necessitates further development. To address these limitations, future improvements should incorporate automatic LED lighting for low-light conditions, real-time internet-based notifications via Telegram or WhatsApp, cloud-based facial data management, and a manual backup system to maintain security and accessibility during power or system failures.

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