Jurnal Kecerdasan Buatan dan Teknologi Informasi
Vol. 5, No. 2, May 2026, pp. 337-343
e-ISSN: 2964-2922, p-ISSN: 2963-6191
DOI : https://doi.org/10.69916/jkbti.v5i2.501

DESIGN OF AN IOT-BASED AUTOMATIC MOSQUE DOOR SYSTEM USING PIR AND CAMERA SENSORS FOR SMART WORSHIP ACCESS

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(Received: May 1, 2026; Revised: May 23, 2026; Published: May 23, 2026)

Abstract

Mosques and mushallas are worship facilities with high congregational activity, requiring a secure, comfortable, and efficient door access system. Manual door operation often causes several problems, such as doors not closing properly, noise caused by slamming doors, and high physical contact between users and the door. This study aims to design and develop an automatic door system based on Passive Infrared (PIR) sensors and surveillance cameras integrated with Internet of Things (IoT) technology to improve security and convenience in mosque and mushalla environments. The research method used is Research and Development (R&D), consisting of system requirement identification, hardware and software design, prototype implementation, testing, and evaluation. The system uses PIR sensors or cameras to detect the presence of worshippers, microcontrollers such as Arduino, ESP32, or Raspberry Pi as the control center, and servo motors or DC motors as automatic door actuators. The system is also equipped with a real-time notification feature through Telegram to send information and visual documentation to administrators. The results show that the system is capable of detecting movement, automatically opening and closing doors, and sending notifications along with visual documentation in real time. The system improves user convenience, reduces physical contact with doors, and facilitates remote security monitoring by administrators. In addition, the use of ESP32-CAM is considered effective and economical for implementing IoT-based automatic door systems.

Keywords: automatic door; PIR sensor; surveillance camera; IoT; mosque.

1. INTRODUCTION

Door management in mosques and mushallas faces challenges due to the high volume of worshippers and the need to maintain cleanliness, comfort, and security within the worship environment. The utilization of Internet of Things (IoT) technology through the integration of Passive Infrared (PIR) sensors with surveillance cameras is one solution that can be implemented to improve security systems and door automation. PIR sensors are capable of detecting human presence based on body infrared radiation, which then triggers the camera to capture images or record videos as event documentation. The data can subsequently be transmitted in real time through IoT platforms such as Telegram or mobile applications, allowing administrators to monitor and control access without direct physical contact. The implementation of this system also supports the concept of IoT-based security that is responsive to user presence around the door area, enabling the door to open or lock automatically according to predetermined conditions [1], [2].

Several previous studies have shown that the combination of PIR sensors and surveillance cameras can improve object detection accuracy while also providing visual evidence in the form of images or videos when activity occurs near the door area. These systems generally utilize devices such as ESP32-CAM, Raspberry Pi, or Arduino connected to Telegram Bots or Android applications as media for notifications and remote access control. When motion is detected, the camera is activated to capture images, and the system sends notifications to administrators through the internet in real time. In addition, automatic door locking mechanisms using relays or solenoid locks can also be activated based on sensor detection results or user verification through IoT applications. This approach is considered capable of increasing flexibility in access management while providing better security documentation compared to conventional systems [3], [4]

In the context of public facilities such as mosques and mushallas, the use of motion sensor-based automatic door systems provides additional benefits by reducing physical contact between worshippers and doors, thereby helping to maintain cleanliness and sanitation in the worship environment. This system can also reduce the risk of doors remaining open for too long, which may allow dust, animals, or external noise to enter the room. Related studies indicate that motion sensor-based automatic doors can improve user comfort because the door opening and closing

process becomes faster and more efficient. Furthermore, the integration of Telegram-based notifications enables administrators to receive direct information through smartphones, including visual evidence in the form of photos or videos that can be used for security verification and activity monitoring [3], [5].

However, the implementation of this technology also requires attention to system reliability and implementation costs. The performance of PIR sensors is influenced by detection distance, sensor viewing angle, environmental temperature conditions, and possible interference from small animals or lighting changes. Therefore, several studies recommend the use of dual PIR sensors or integration with cameras to improve human detection accuracy. In addition, internet network quality and the performance of IoT platforms such as Telegram also affect notification delivery speed and image transfer performance. Differences in device architecture, such as the use of ESP32-CAM compared to Raspberry Pi, also influence communication latency, bandwidth requirements, and system programming complexity [6], [7], [8].

Besides focusing on security and automation, this research also considers operational ergonomics and cost efficiency in public facilities. Previous literature emphasizes that automatic door systems should consider motor noise levels, mechanical wear, energy consumption, and ease of use for worshippers and mosque administrators. The integration of additional sensors such as light sensors, temperature sensors, or IoT-based CCTV systems can also be applied to improve overall comfort and security within worship environments. Evaluation of total implementation and operational costs is important to ensure that the designed system remains economical and can be implemented gradually according to the needs of worship facility administrators [9], [10], [11].

Based on the explanation above, this research aims to design and develop a prototype of an automatic door system based on PIR sensors and surveillance cameras for mosques or mushallas with IoT notification support through Telegram. The system is designed in two architectural variants, namely the integration of PIR sensors with surveillance cameras and camera-based motion detection equipped with automatic locking mechanisms and remote control through IoT platforms. This study will also evaluate system performance, including detection accuracy, door response speed, notification latency, image transfer time, noise level, and mechanical wear of the door. In addition, the study considers aspects of data security, ease of use, and implementation cost efficiency to ensure that the system can be effectively applied in public worship facilities. The final results of this research are expected to include system architecture design, functional prototypes, performance evaluation, and implementation guidelines that can be replicated in various mosques and mushallas [2], [12], [13].

2. RESEARCH METHODS

The research method used in this study is the Research and Development (R&D) method with an approach focused on designing and evaluating a prototype of an automatic door system based on Passive Infrared (PIR) sensors and camera sensors. This method was chosen because the objective of the research is not only theoretical analysis, but also the development of a product in the form of an automatic door system prototype that can be implemented in mosque or mushalla environments. The R&D approach enables the development process to be carried out systematically through literature studies, conceptual design, system implementation, testing, and evaluation to produce a system that can be replicated and implemented by worship facility administrators [9], [14]

The initial stage of the research involved identifying system requirements by collecting data related to the environmental conditions of mosques or mushallas, such as door position, light intensity, worshipper activity levels, and the need for secure and comfortable door access. In addition, an analysis of component specifications was conducted, including sensor detection range, power consumption, device compatibility, and data communication capabilities through IoT platforms such as Telegram [10]

At the design stage, the system was developed using PIR sensors or camera sensors to detect the presence of worshippers in real time. The sensors were connected to microcontrollers such as Arduino Uno, ESP32, or Raspberry Pi, which functioned as the main control center of the system. Detection data were processed by the microcontroller to control the door actuator in the form of a servo motor or DC motor. In addition, the system was designed to send notifications and image documentation through IoT platforms such as Telegram or Android applications, enabling administrators to monitor the door condition remotely [6], [10], [14]

The implementation stage was carried out by assembling all main components, including PIR sensors, cameras, microcontrollers, door actuator motors, relays, breadboards, and jumper cables into an integrated system. Programming was then performed using Arduino IDE or other programming environments to regulate motion detection, automatic door control, and image notification delivery through Telegram or other IoT platforms.

After the system had been designed, the next stage involved prototype testing to determine the level of success and overall system performance. The testing process included sensor detection accuracy, door opening and closing response time, system stability, power consumption, and the capability of delivering real-time notifications. Testing was also conducted under various environmental conditions, such as changes in light intensity and variations in worshipper activity levels, to evaluate the reliability of the system under actual operational conditions. The testing results were then analyzed as the basis for system evaluation and improvement in order to produce an automatic door system that is effective, secure, and easy to use in mosque or mushalla environments

2.1. Research Procedure

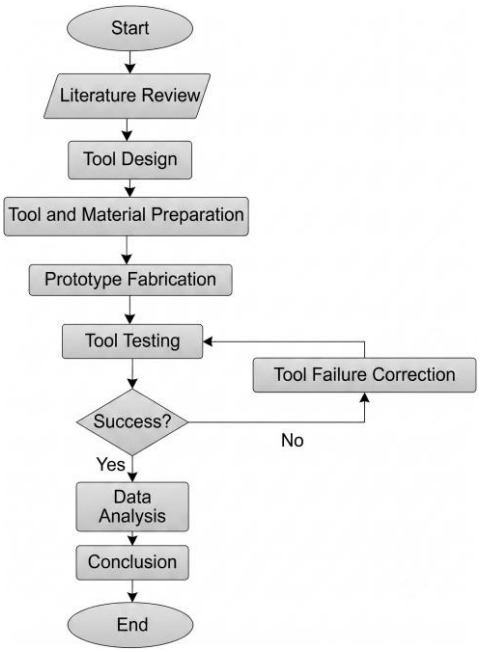

Figure 1. Research Procedure

The research procedure was carried out systematically, starting from the literature review stage to the conclusion stage. The first stage began with determining the research topic and identifying problems related to the automatic door system for mosques or mushallas. Furthermore, a literature review was conducted by collecting various references from journals, books, and previous studies related to PIR sensors, cameras, the Internet of Things (IoT), microcontrollers, and automatic door systems. The literature review aimed to obtain theoretical foundations and understand technological developments relevant to the research.

The next stage was system design, which involved designing the hardware and software architecture of the system. The design process included selecting the main components such as PIR sensors or cameras, microcontrollers, door actuator motors, relays, and IoT platforms used for system notifications and monitoring. After the design stage was completed, the preparation of tools and materials was carried out, including PIR sensors, cameras, microcontrollers, door actuator motors, jumper cables, breadboards, laptops, and other supporting equipment.

At the prototype development stage, all components were assembled into an integrated automatic door system. In addition, microcontroller programming was performed to regulate motion detection, automatic door control, and notification delivery through Telegram or other IoT platforms. After the prototype had been completed, system testing was conducted to evaluate system performance, including sensor detection accuracy, door opening and closing response speed, system stability, power efficiency, and the capability of sending real-time notifications.

If errors were found during the testing stage or the system did not operate according to the intended objectives, corrections were made to both hardware and software components. After improvements were completed, the system was retested until the expected performance targets were achieved. Furthermore, the testing data were analyzed quantitatively to determine the success rate of the system, sensor accuracy, and operational efficiency of the automatic door system. The final stage of the research involved drawing conclusions based on the results of data analysis and providing recommendations for future system development. After all stages had been completed, the research was declared finished, and the results were compiled into a final research report.

2.2. System Working Mechanism

The automatic door system operates when the PIR sensor or camera detects the presence of worshippers around the mosque or mushalla entrance. The detection data are then sent to the microcontroller for processing. The microcontroller subsequently sends commands to the door actuator motor, either a servo motor or a DC motor, to automatically open the door. After no movement is detected for a certain period of time, the system automatically closes the door and activates the locking mechanism using a solenoid lock to ensure the door remains securely locked.

In addition to functioning as an automatic door system, the integrated camera is also used to capture images or record videos of conditions around the entrance whenever specific activities are detected. The documentation is then sent through Telegram or other IoT platforms as notifications to mosque or mushalla administrators. Through this

system, administrators are able to monitor the door condition in real time, improve the security of worshipper access, and store visual evidence that can be used for security verification purposes when needed.

3. RESULTS AND DISCUSSION

3.1. System Design

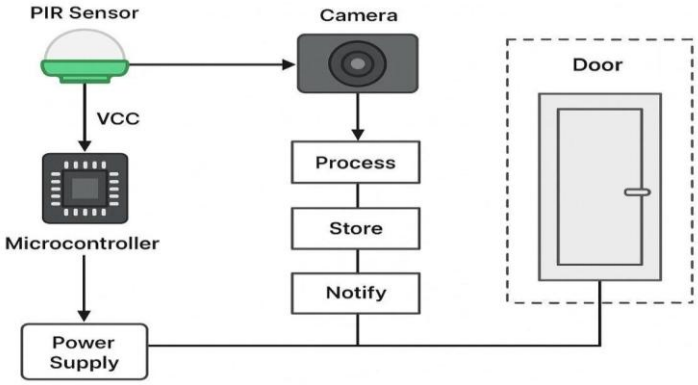

Figure 2. System Design

The system design results indicate that the prototype of the automatic door system based on Passive Infrared (PIR) sensors and surveillance cameras was able to operate according to the designed concept. The system was developed by integrating PIR sensors as motion detectors, cameras as visual documentation devices, microcontrollers as the control center, door actuators in the form of servo motors or DC motors, and IoT platforms for real-time notification delivery. The integration of these components produced an automatic door system capable of improving security, comfort, and operational efficiency in mosque or mushalla environments.

During the functional testing stage, the PIR sensor successfully operated as the initial detector of individual presence in the entrance area. When movement was detected, the sensor transmitted a signal to the microcontroller as a trigger to execute the next process. This mechanism demonstrated that the PIR sensor performed effectively as a motion detection system for door areas, especially within the sensor's detection range. These findings are consistent with previous studies stating that PIR sensors are effective for detecting human movement in security and automatic door systems [1], [15].

After the PIR sensor detected movement, the microcontroller automatically activated the camera to capture images or record videos of the area around the entrance. The testing results showed that the camera was capable of producing sufficiently clear visual documentation to be used as evidence of activity and security verification. The integration of PIR sensors with surveillance cameras provided advantages because the system not only detected movement but also automatically generated visual evidence whenever activity occurred in the entrance area. These findings support previous studies indicating that the combination of PIR sensors and cameras improves the effectiveness of IoT-based security systems [12].

The captured image data were then processed using microcontrollers or single-board computers such as Arduino, ESP32, or Raspberry Pi. Based on the implementation results, image data could be stored on local storage media such as SD Cards or uploaded to cloud-based storage depending on system requirements. The use of cloud storage provided advantages in terms of easier data access and long-term documentation storage. However, cloud-based storage requires a stable internet connection to ensure smooth data transmission. These results are in line with previous studies that implemented local and cloud storage in IoT-based security systems to support continuous visual documentation [16].

In addition to detection and documentation functions, the system successfully delivered real-time notifications through IoT platforms such as Telegram, WhatsApp, or email. The testing results showed that notifications could be received by administrators within a relatively short time when the network connection was stable. The transmitted information included motion detection status along with captured images or videos. This feature provides convenience for mosque or mushalla administrators to remotely monitor door conditions without being physically present at the location. These findings support previous research stating that IoT-based notification systems can improve security response and real-time monitoring effectiveness [13], [17]

In terms of the door control mechanism, the microcontroller successfully controlled the actuator in the form of a servo motor or DC motor to automatically open and close the door. When movement was detected, the door opened automatically, while after no activity was detected for a certain period, the system closed the door again and activated the solenoid lock as an automatic locking mechanism. The testing results indicated that the opening and closing mechanism operated effectively and was able to reduce physical contact between worshippers and the door. The system was also considered capable of improving worshipper comfort, particularly during periods of high user activity

such as Friday prayers or other religious events. The concept of integrating motion sensors, cameras, and door actuators into a single system has also been applied in various security-based automatic door system studies [3]

From the hardware perspective, each component demonstrated complementary functions in supporting the overall system. The PIR sensor functioned to detect human presence around the door, the camera generated visual documentation, while the microcontroller acted as the data processing center and system controller. The power supply also played an important role in maintaining stable voltage to ensure continuous system operation without interruptions. The implementation results showed that the ESP32-CAM provided advantages in terms of cost and efficiency because it integrates both camera modules and Wi-Fi connectivity within a single device. However, Raspberry Pi offers higher data processing capability, making it more suitable for future developments involving computer vision or face recognition technologies[10]

Regarding future system development, the research results indicate that the system can still be further improved by integrating computer vision algorithms such as face recognition or object classification to enhance security and user identification accuracy. The implementation of such technologies would allow the system not only to detect movement but also to recognize the identity of users accessing the door. Previous studies have shown that the application of face recognition in door security systems can improve user verification accuracy and minimize unauthorized access [16], [18], [19].

3.2. Blackbox Testing

The system testing method used in this study is the Black Box Testing method. Black Box Testing is used to evaluate system functionality based on inputs and outputs without examining the internal program structure or source code. The testing process was conducted to ensure that each component and feature of the automatic door system operated according to its intended function.

Black Box Testing was applied to several main parts of the system, including testing the PIR sensor or camera in detecting the presence of worshippers, testing the automatic door opening and closing mechanism, testing notification delivery through IoT platforms such as Telegram, and testing actuators such as servo motors, DC motors, and solenoid locks. In addition, the system response was also tested under various environmental conditions, such as changes in light intensity, sensor detection distance, and activity levels around the door area.

Table 1. Testing Results

No	Component Tested	Input/Testing	Expected Output	Result
1	PIR Sensor	Object/human moves in front of the sensor	Sensor detects movement and sends a signal to the microcontroller	Success
2	Camera	PIR sensor detects movement	Camera activates and captures images/videos	Success
3	Servo Motor / DC Motor	Sensor detects the presence of worshippers	Door opens automatically	Success
4	Solenoid Lock	No movement detected for a few seconds	Door closes and locks automatically	Success
5	Telegram Notification	Movement detected by the sensor	Notification and image sent to Telegram	Success
6	IoT System	Internet connection active	System sends data in real-time	Success
7	Power Supply	System powered on	All components receive power and operate normally	Success
8	Sensor Distance Testing	Object positioned at a certain distance	Sensor is still able to detect the object	Success

Based on the testing results using the Black Box Testing method, all main functions of the automatic door system operated according to the design. The PIR sensor successfully detected movement, the camera was able to capture visual documentation, and the system successfully sent real-time notifications through Telegram. In addition, the servo motor or DC motor was capable of opening and closing the door automatically according to the specified conditions. Therefore, the system is considered to function properly and can be implemented in mosques or prayer rooms to improve security and user convenience.

3.3. Expected System Performance

The proposed automatic door system is expected to provide effective performance in supporting accessibility, security, and convenience within mosque and prayer room environments. Through the integration of Passive Infrared (PIR) sensors or camera sensors with microcontrollers and Internet of Things (IoT) technology, the system is designed to automatically detect the presence of worshippers around the entrance area and respond by opening or closing the door according to predefined operational conditions. The proposed mechanism is expected to reduce direct physical

contact with doors, thereby supporting environmental cleanliness and improving user comfort, particularly during periods of high worshipper activity.

In terms of system responsiveness, the proposed design is expected to enable relatively fast motion detection and door actuation processes through the use of microcontrollers such as ESP32, Arduino, or Raspberry Pi. The integration of surveillance cameras is also expected to improve monitoring capability by providing visual documentation of activities occurring around the entrance area. Furthermore, the implementation of IoT communication platforms such as Telegram is expected to facilitate real-time notification delivery to mosque or prayer room administrators, enabling remote monitoring and quicker responses to security-related events.

From the operational perspective, the system is expected to maintain stable functionality under normal environmental conditions while supporting automatic door operation with minimal user intervention. The use of integrated components such as servo motors, solenoid locks, and wireless communication modules is also expected to contribute to efficient door control and enhanced security management. However, actual system performance may vary depending on environmental conditions, sensor sensitivity, internet connection quality, and hardware specifications used during future implementation stages. Therefore, prototype testing and performance evaluation are recommended for future studies to validate the effectiveness and reliability of the proposed system under real operational conditions.

3.4. Discussion

Based on the discussion regarding system reliability, the performance of the PIR sensor is influenced by several environmental factors, such as room temperature, light intensity, the presence of small animals, and the position of sensor installation. Under certain conditions, the sensor may generate false triggers due to temperature changes or the movement of other objects around the door area. Therefore, proper sensor placement and sensitivity adjustment are important factors to ensure more optimal detection performance. In addition, internet network quality also affects the speed of notification delivery and visual documentation transmission. The more stable the internet connection used, the lower the latency in sending data to the administrator's device.

From an ergonomic perspective, the implementation of an automatic door system based on PIR sensors and cameras is considered capable of improving worshipper comfort by reducing the need for direct physical contact with the door, maintaining the cleanliness of the worship environment, and accelerating access for worshippers entering and leaving the mosque or mushalla. The system can also help reduce noise caused by slamming doors and minimize the risk of doors being left open for too long. Meanwhile, in terms of implementation cost, the use of devices such as ESP32-CAM is considered a more economical alternative compared to Raspberry Pi because it offers lower cost while still providing adequate camera integration and IoT connectivity for automatic door system applications in mosques or mushallas. Therefore, the designed system has the potential to be widely implemented in worship facilities with relatively affordable costs while still providing optimal security and comfort functions.

4. CONCLUSION

Based on the research results, the automatic door system based on PIR sensors and surveillance cameras was successfully designed and implemented to improve security, comfort, and access efficiency in mosques or prayer rooms. The PIR sensor was able to detect the presence of worshippers effectively and functioned as the main trigger for activating the camera and the automatic door opening and closing mechanism. The integration of cameras and IoT platforms such as Telegram also enabled administrators to monitor the system and receive notifications in real time. The testing results showed that the system operated according to the planned functions, including motion detection, visual documentation, notification delivery, and automatic door actuator control. In addition to improving security, the system also reduced physical contact with the door, thereby supporting cleanliness and comfort within the worship environment. However, system performance was still influenced by environmental conditions such as temperature, light intensity, sensor placement, and internet network stability. In terms of implementation, the ESP32-CAM was considered more economical and sufficiently effective for IoT-based automatic door systems in mosques or prayer rooms. Therefore, this study demonstrates that an automatic door system based on PIR sensors and cameras has strong potential to be widely implemented as a modern security and automation solution for worship facilities.

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