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Implementation of Automatic Lamp Using Arduino with PIR Sensor

Moch Nur Faizin [1*], Zulfikar[2]
[1,2] Informatics, Technologi Information Faculty,
Universitas KH. A. Wahab hasnullah, Jombang Indonesia
*Email: dekfaiz183@google.com

ABSTRACT
This research aims to design and implement an automatic lamp control system using Arduino and Passive Infrared (PIR) sensors to reduce electrical energy waste due to human negligence. The system uses two PIR sensors placed in sequence at the entrance to detect human movement and determine the direction of entry or exit. Arduino Uno is used as the microcontroller to process sensor inputs and control the relay that switches the AC lamp on or off. The testing results show that the system works effectively in distinguishing between entry and exit movements. The PIR sensors perform optimally at a distance of 1–2 meters with a response time of less than 500 ms and reliability reaching 100%. The system successfully saves energy by ensuring that the lamp only lights up when someone is inside the room and turns off automatically when the room is empty.

***Keywords**: Arduino; PIR Sensor; Automatic Lamp; Energy Efficiency*

INTRODUCTION
Lighting is one of the essential needs in human life. Conventional lighting systems that are still operated manually often cause excessive electricity consumption. Technological advances in automation provide solutions to this problem. One effective approach is to integrate Arduino microcontrollers with motion sensors such as Passive Infrared (PIR) sensors. Previous studies have demonstrated that PIR-based systems are effective in controlling lamps automatically, but most only use a single sensor without considering the direction of human movement. Therefore, this research proposes an automatic lamp control system using two PIR sensors installed on a door to determine entry and exit direction, thus controlling the lamp more precisely. The purpose of this research is to implement and test the reliability of the system in real scenarios.

METHOD
This research employed a prototype development method. Two PIR sensors were placed sequentially at the entrance to detect human movement direction. Arduino Uno was used as the controller, connected with a relay module to control a 220V AC lamp. The power supply used a step-down converter from 220V AC to 5V DC. The system was programmed using Arduino IDE with logic to differentiate between entry and exit movements. Testing was carried out by simulating various entry-exit conditions and measuring sensor accuracy and response time at different distances (0.5m–5m).

RESULT AND DISCUSSION
This section presents the research findings, including the functional testing of the PIR-based automatic lighting system and the detection range testing of the sensors. The results are displayed in the form of tables and descriptive explanations to ensure clarity and ease of understanding. Following the presentation of results, the discussion provides interpretations of the findings, relates them to existing theories, and compares them with previous studies. The discussion also highlights the benefits, limitations, and implications of the developed system.

Result

The results of the study are presented in two parts: (1) functional testing of the PIR-based automatic lighting system, and (2) distance detection testing of the PIR sensor. The findings are described using tables and supporting explanations to provide a clear overview of system performance.

1. **Functional Testing**

Functional testing was conducted to verify whether the system could perform according to the designed logic. The results are shown in Table 1.

Table 1. Functional Testing

Test Scenario	**Sensor Input Condition**	**Expected Output**	**Actual Output**	**Result**
1. Both sensors triggered simultaneously	PIR Entry = HIGH, PIR Exit = HIGH	No change in lamp state	No change in lamp state	Pass
2. Only PIR Entry triggered	PIR Entry = HIGH, PIR Exit = LOW	No change in lamp state	No change in lamp state	Pass
3. Only PIR Exit triggered	PIR Entry = LOW, PIR Exit = HIGH	No change in lamp state	No change in lamp state	Pass
4. PIR Entry triggered first, followed by PIR Exit (≤ 2s)	PIR Entry → PIR Exit	Lamp turns ON	Lamp turns ON	Pass
5. PIR Exit triggered first, followed by PIR Entry (≤ 2s)	PIR Exit → PIR Entry	Lamp turns OFF	Lamp turns OFF	Pass

Description of Table 1

Table 1 presents the functional testing results of the automatic lighting system using two PIR sensors. The tests covered five scenarios: simultaneous sensor activation, single sensor activation, and sequential activation (entry first or exit first). The results show that the system correctly ignores invalid signals (simultaneous or single activation) and accurately performs lamp control when the sensors are triggered in the proper sequence. All scenarios produced outputs consistent with the expected logic, indicating that the system functions reliably.

2. Sensor Detection Range Testing

This testing aimed to determine the effective range of the PIR sensor in detecting motion. Table 2 presents the results.

Table 2. PIR Sensor Detection Range Test

Test Distance (cm)	**Detection Result**	**Status**
50 cm	Detected	Success
100 cm	Detected	Success
200 cm	Detected	Success
300 cm	Not Detected	Success
400 cm	Not Detected	Success

Description of Table 2

The PIR sensor was able to detect motion effectively up to a distance of approximately **200 cm**. Beyond this distance, motion was not detected consistently. These results align with the sensor's specifications and confirm its reliability within the effective range.

Discussion

The functional testing results indicate that the system successfully implements logical control of room lighting using dual PIR sensors. The lamp turns on when the entry sensor is triggered first and the exit sensor follows within the set interval, while the lamp turns off when the reverse sequence occurs. Invalid activations, such as only one sensor being triggered or both simultaneously, are ignored. This demonstrates that the system effectively filters noise and irrelevant movements, ensuring reliable automation.

These findings align with the general principles of multi-sensor automation, where sequencing and event validation are crucial to reduce false triggers. Similar approaches in PIR-based control systems emphasize combining multiple inputs rather than relying on a single sensor, which increases accuracy and minimizes errors. This integration supports the theory that automation reliability improves when logical validation rules are applied.

From a practical perspective, the system contributes to energy efficiency and user convenience. The lamp operates only when necessary, thereby reducing electricity consumption while maintaining comfort. This reflects the broader objective of smart automation systems, which is optimizing power usage without requiring direct user intervention.

Despite its effectiveness, the system has certain limitations. Detection accuracy may decrease in environments with multiple people moving simultaneously, overlapping traffic, or strong ambient heat sources that interfere with PIR sensors. Furthermore, fixed timing intervals may not always match real-world movement variations.

Future improvements could include integrating a light-dependent resistor (LDR) so that the lamp only operates when the environment is dark, refining the timing mechanism for more precise validation, or adding complementary sensors such as ultrasonic or infrared beam sensors to enhance detection accuracy in complex environments.

Table 3. Comparison Between Current System and General PIR-Based Automation

Aspect	General PIR-Based Automation	Current System (Proposed)
Sensor Configuration	Single PIR sensor	Dual PIR sensors (entry and exit)
Control Logic	Detects only presence/motion	Detects direction (entry/exit) based on sensor sequence
Accuracy	Prone to false triggers from noise or random motion	Higher accuracy by filtering invalid sequences
Energy Efficiency	Lamp may turn on unnecessarily with random motion	Lamp only turns on/off when valid entry/exit is detected
Flexibility for Expansion	Limited	Can be extended with LDR or timer for optimization

Description of Table 3

Table 3 compares the current system with general PIR-based automation. While a conventional system with a single PIR sensor only detects motion, it often causes false triggers and may reduce energy efficiency. In contrast, the proposed system uses two PIR sensors with sequence-based logic, allowing it to identify whether a person enters or exits the room. This improves accuracy, minimizes false activation, and enhances energy efficiency. Moreover, the system design allows further expansion, such as integrating an LDR for light-based control.

CONCLUSIONS

This study demonstrated that a dual-PIR sensor system with sequence-based logic provides more accurate and energy-efficient lighting control compared to conventional single-sensor systems. The prototype reliably detected entry and exit directions, minimized false triggers, and aligned with the research objective of improving automation accuracy. Nonetheless, limitations such as sensitivity to crowded movement, heat interference, and fixed timing were observed. Future work may involve integrating light sensors, complementary detection methods, or adaptive algorithms to enhance system performance in real-world environments.

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