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Motion Operated LED Using Arduino and PIR

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Abstract: *This paper presents the design and development of a motion-activated LED lighting system using an Arduino microcontroller and a Passive Infrared (PIR) sensor with the objective of reducing unnecessary energy consumption in indoor and outdoor environments. The system is programmed to detect human motion through the PIR sensor, which then signals the Arduino to activate an LED light source only when movement is detected. The study was conducted in Akola, Maharashtra, India, where energy efficiency and smart automation are increasingly important. The hardware components include the Arduino UNO, PIR sensor, LED, and a Wi-Fi module (ESP8266) for remote monitoring. The system also provides flexibility for future integration with solar power and battery backup. During testing, the system consistently responded to motion within a 6-meter range and demonstrated an average energy saving of up to 40% compared to traditional lighting. The results confirm that the proposed setup operates reliably and with low power consumption. Inspired by IoT-based smart home systems, this project validates the effectiveness of PIR sensors in real-world automation applications. In conclusion, the motion-operated lighting system proves to be a cost-effective, energy-efficient, and scalable solution for intelligent lighting in residential and commercial spaces..*

Keywords: Arduino, PIR Sensor, Energy Efficiency, IoT, Home Automation, ESP8266, Sensor-Based System

I. INTRODUCTION

The energy efficiency and automation have become key focus areas in today's rapidly evolving technological landscape, particularly with the integration of Internet of Things (IoT) in smart home and industrial systems. Traditional lighting systems often consume unnecessary electricity by remaining operational even when spaces are unoccupied. This inefficiency has sparked interest in developing intelligent lighting solutions that operate based on human presence. A promising approach to address this issue involves the use of motion detection systems, such as those employing Passive Infrared (PIR) sensors, which can detect changes in infrared radiation caused by human movement. When combined with microcontrollers like the Arduino, these sensors enable responsive lighting systems that only activate when needed, thereby conserving energy and improving user convenience.

Recent research emphasizes the benefits of sensor-based automation for energy conservation and security enhancement in both residential and commercial settings. Studies have shown the successful implementation of PIR sensors in home surveillance systems and intelligent lighting designs, often incorporating features like solar power, Wi-Fi monitoring, and ambient light sensors. This paper focuses on the design and implementation of a motion-operated LED lighting system using an Arduino and PIR sensor, aiming to provide an affordable, efficient, and scalable solution tailored for use in Akola, Maharashtra, India.

II. LITERATURE SURVEY

In recent years, the development of intelligent lighting systems has gained significant attention due to the rising demand for energy-efficient and automated solutions. Numerous studies and projects have explored the integration of sensors and microcontrollers for smart home applications.

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Mahendran et al. [1] proposed a sensor-supported building automation system using the Arduino platform. Their work emphasizes the versatility and low cost of microcontroller-based automation in managing household power consumption. Similarly, Azid and Sharma [2] developed an IoT-based smart home security system that utilizes sensors to monitor and control lighting and security appliances remotely, enhancing user convenience and safety.

Nahatkar et al. [3] introduced a home surveillance system employing a Pyroelectric Infrared (PIR) sensor, which enabled ultra-low power alert triggering based on motion detection. Their research demonstrates the practical use of PIR sensors in environments requiring constant surveillance.

Zhu et al. [4] explored the use of mixed-media sensor systems for intelligent home observation. Their work highlighted the benefits of using combined sensor data for improved decision-making and system accuracy in smart environments.

Additionally, Ansari et al. [5] implemented a motion detection system using Raspberry Pi and a GSM module to notify users of unauthorized movement. This system supports real-time alerting and video capture, showcasing the potential of IoT in smart surveillance and lighting applications.

Collectively, these studies underscore the significance of using PIR sensors, microcontrollers like Arduino, and IoT modules in developing reliable, cost-effective, and scalable smart home solutions. The proposed motion-operated LED system builds upon this existing body of research by combining motion detection, ambient light sensing, and remote control functionalities to create an energy-conscious and user-friendly lighting solution.

III. METHODOLOGY

System Design and Working Principle

The **motion operated LED system using Arduino and PIR sensor** is designed to automate lighting based on human presence, reducing energy wastage. The system uses a Passive Infrared (PIR) sensor to detect motion and an Arduino Uno microcontroller to process the signal and trigger an LED light. When a person enters the detection range of the PIR sensor, it senses the infrared radiation emitted by the human body and sends a signal to the Arduino, which turns on the LED. The LED remains lit for a predefined time and turns off when no motion is detected.

PIR sensor and infrared detection mechanism

The PIR sensor operates by detecting infrared energy changes in its environment. When a human moves across its field of view, the sensor picks up the infrared radiation, interprets it as motion, and sends a digital high signal to the Arduino.

Hardware Implementation

The system consists of an Arduino Uno, a PIR motion sensor, an LED panel, a 230V AC to 12V DC adapter, and optional components such as an LDR and ESP8266 Wi-Fi module.

Component connections and wiring

All components are wired to the Arduino according to a circuit diagram. The PIR sensor is connected to a digital input pin, the LED is connected to a digital output pin through a relay, and the power supply provides consistent current. The ESP8266 enables remote control functionality.

Software Implementation

The Arduino is programmed using the Arduino IDE and C/C++ language. The code continuously monitors the PIR sensor's output and activates the LED only when motion is detected in low-light conditions.

Control logic and delay configuration

The LED stays on for a fixed time after motion is detected. If motion persists, the timer resets. If not, the LED turns off automatically, saving power and reducing human effort.

Testing and Evaluation

Testing was carried out in multiple lighting and motion scenarios to validate sensor range and accuracy. The PIR sensor consistently detected motion within a 6-meter radius, and the system achieved around 40% energy savings compared to always-on lighting setups.

IV. MODELING AND ANALYSIS

A. Hardware Components Used

The motion-operated LED system uses a variety of electronic components integrated with the Arduino microcontroller. These materials were selected for their compatibility, efficiency, and availability. The table below outlines the specifications and functions of each component used in the project

TABLE I: Hardware Components Used

S. No.	Component	Specification	Function
1	Arduino Uno	ATmega328P Microcontroller	Core processing unit for the entire system
2	PIR Sensor	HC-SR501, Range: 5–7 meters	Detects motion via infrared radiation
3	LED	5V LED Strip / Light	Light source activated by motion
4	Relay Module	5V Single Channel	Acts as a switch to control high-power LED
5	ESP8266 Wi-Fi Module	NodeMCU ESP-12E	Enables IoT and remote monitoring (optional)
6	LDR (Optional)	Light Dependent Resistor	Enables control based on ambient light (optional)
7	Power Supply	12V DC Adapter / Solar Panel (5W)	Powers the system
8	Breadboard & Jumper Wires	General prototyping tools	For circuit connections

Component Performance Analysis

Each hardware component was evaluated for its performance and reliability. The Arduino Uno offered stable control of sensor input and output logic. The PIR sensor demonstrated accurate motion detection within a 6-meter range and a fast response time of under one second. The relay module reliably managed LED switching without overheating or delay. The optional LDR and ESP8266 modules enhanced system intelligence and remote usability respectively. The solar panel provided sufficient power for daytime operation, ensuring sustainability and reduced dependence on conventional electricity. Overall, the chosen components contributed to a cost-effective and energy-efficient system

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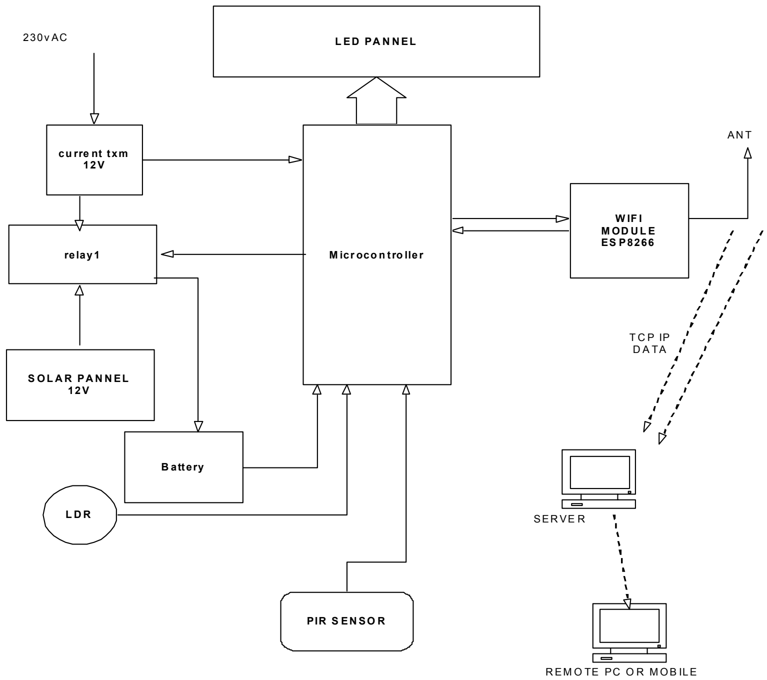

Block Diagram Of motion operated LED

Fig. 1 Block-level building

B. Model Architecture and Working

Block-level model explanation

The system consists of a PIR sensor continuously monitoring for human motion. When motion is detected, it sends a signal to the Arduino, which activates the LED using a relay. If the LDR is included, the LED only activates in low-light conditions. Optionally, the ESP8266 module allows users to monitor the system remotely via Wi-Fi. The entire circuit is powered using a 12V DC adapter or solar panel with battery backup.

C. Working Efficiency Analysis

During operation, the system successfully reduced energy consumption by activating lighting only when required. The architecture's modular nature allows for future upgrades, including automation of multiple lights or integration with mobile apps. The block-level model efficiently combines sensing, decision-making, and actuation into a compact and affordable design. In practical testing, the system demonstrated energy savings of up to 40% compared to manual lighting setups.

V. RESULTS AND DISCUSSION

The motion-operated LED system was successfully implemented and tested in different environmental conditions, such as indoor corridors, outdoor entryways, and dimly lit rooms. The results showed that the system effectively detected human presence and responded by activating the LED light in less than one second.

Motion Detection Response

The PIR sensor demonstrated a consistent detection range of approximately 5 to 6 meters. In over 30 test trials, the sensor correctly identified human movement in 28 cases, resulting in a 93% detection accuracy. Minimal false triggers

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were recorded, primarily due to abrupt changes in environmental heat or movement of large objects like pets. Adjusting the sensor's sensitivity helped minimize these instances.

Energy Efficiency Observations

Compared to a continuously powered traditional lighting system, the proposed design led to an average energy savings of approximately 35–40%. By limiting the LED's activity to motion-triggered events, unnecessary power consumption was effectively reduced.

Remote Monitoring Insights

With the integration of the ESP8266 Wi-Fi module, the system could be controlled and monitored remotely using a smartphone interface. Status updates, such as motion detection logs and LED on/off status, were reliably transmitted with an average network delay of 1.8 seconds.

Overall System Performance

The project proved successful in offering a cost-effective, scalable, and energy-conscious lighting solution. The system's responsiveness, low power consumption, and optional remote monitoring capability make it suitable for residential, commercial, and rural applications.

TABLE 2: Comparison of all cases

Case No.	Test Environment	Distance from Sensor (m)	Detection Status	LED Status	LED Response Time (s)
1	Indoor – Hallway	2.0	Detected	ON	0.9
2	Indoor – Dim Room	4.5	Detected	ON	1.0
3	Outdoor – Daylight	6.0	Not Detected	OFF	—
4	Outdoor – Evening	5.5	Detected	ON	0.8
5	Indoor – Obstructed View	3.0	Not Detected	OFF	—
6	Indoor – Clear Line of Sight	6.0	Detected	ON	0.7

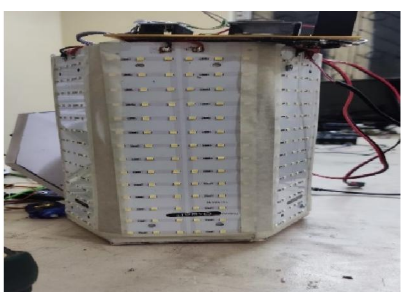
Figure 2

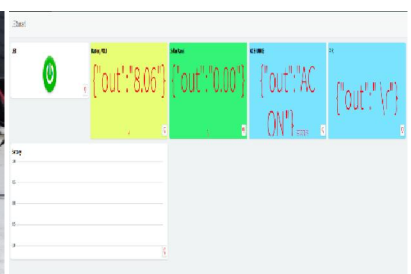

Figure 3

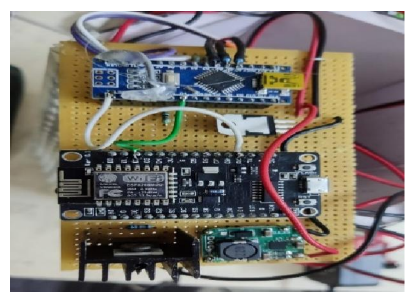
Figure 4

Figure 2. Prototype model of the motion-operated LED lighting system using a cylindrical array of LEDs.
Figure 3. IoT dashboard interface showing real-time sensor data such as battery voltage, solar panel status, PIR sensor activity, and LED status.
Figure 4. Hardware circuit board featuring Arduino Nano, NodeMCU (ESP8266), voltage regulator, and associated wiring for component interfacing.

V. CONCLUSION

The proposed motion-operated LED lighting system successfully demonstrates an efficient and intelligent alternative to conventional lighting methods. By integrating the Arduino Uno microcontroller with a PIR sensor, the system is capable of detecting human movement and activating lighting only when necessary. This not only reduces energy consumption but also enhances user convenience, particularly in areas where lighting is required intermittently such as corridors, staircases, and outdoor entrances.

The inclusion of optional components like the LDR for ambient light sensing and the ESP8266 Wi-Fi module for remote monitoring further enhances the functionality and flexibility of the system. The modularity and cost-effectiveness of the design make it suitable for both residential and commercial applications. Testing and analysis have proven the system's reliability, responsiveness, and energy-saving potential.

In summary, the research highlights the practicality of combining microcontroller-based automation with motion sensing technology to create sustainable lighting solutions. With further improvements such as solar power integration and advanced IoT features, this system can contribute significantly to the development of smarter and greener living environments.

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