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Development Prototype of Smart Lighting Control System (SLCS) with IoT-based Application

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Abstract: The goal of this research project is to create a prototype for a smart lighting control system that incorporates Internet of Things (IoT) technologies. The prototype incorporates LED luminaires outfitted with light sensors and passive infrared (PIR) sensors, allowing automatic switching of the AC bulb based on observed light levels and movement. Furthermore, the system employs Blynk Apps as an IoT application, allowing manual control of the AC light via smartphones. The prototype was tested and evaluated in a controlled laboratory environment, using multiple scenarios and metrics to validate its functionality and performance. The results proved the prototype's ability to detect light levels below the 185-lux threshold and movement using the PIR sensor. Furthermore, the integration of the Blynk Apps IoT application demonstrated the AC bulb's flawless control via smartphone contact. The feedback from the testing phase generated tweaks and enhancements to ensure the prototype's dependability and usability. Overall, by demonstrating the successful integration of sensors and IoT technology, this research study contributes to the growth of smart lighting technology and IoT applications, paving the way for more efficient and convenient smart lighting solutions in a variety of contexts.

Keywords: Illuminance, Smart Lighting Control System (SLCS), Lux, Internet of Things (IoT), Blynk

1. Introduction

Smart lighting management systems with Internet of Things applications have emerged as a promising alternative for enhancing energy efficiency, comfort, and security in a variety of settings [1]. Digital sensors, communication interfaces, and actuators are used in these systems to modify lighting conditions based on user preferences, ambient factors, and occupancy status. The integration of smartphones, smart speakers, building management systems, and cloud services improves functionality and allows for remote monitoring [2].

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The goal of this research project is to create a prototype of a smart lighting control system for a specific use case using IoT applications. The prototype is made up of LED luminaires outfitted with light sensors and passive infrared (PIR) sensors, a central control unit running complex algorithms, and an interactive user interface [3]. It intends to demonstrate capabilities such as automatic on/off switching of bulbs based on detected light levels and occupancy, which will provide convenience and eliminate the need for manual control. Furthermore, the system encourages energy-saving practices by optimizing lighting usage via sensor-based control [4].

Thorough testing and assessment in a controlled laboratory setting will validate the prototype's functionality and performance. This testing phase's findings will influence essential refinements prior to eventual real-world implementation. This study advances smart lighting technology and IoT applications by demonstrating the potential benefits of smart lighting control systems. The findings will be useful for future research and development in this subject, allowing for the adoption of smarter and more efficient lighting solutions.

2. Materials and Methods

To develop a better understanding of this study, research on the specification of the sensors, precautions on working with the AC source, a sketch of the coding for the system and also the Blynk application that can be implemented in the system was conducted. Firstly, the development of the components in one system needs to be studied before implementing the Blynk application in the SLCS system. After that, the coding for the SLCS needs to be sketched in one coding which enables the system to function as the actual.

2.1 Materials

Table 1 shows the software and hardware requirements for the Smart Lighting Control System (SLCS) with IoT Applications. The complex coding that has an algorithm will be done using Arduino IDE then after compiling the coding, the sensors will be activated and can give the input to the NodeMCU as the microcontroller to switch ON/OFF the AC bulb. The coding for IoT implementation in the system also needs to be compiled using the Arduino IDE. After that, the NodeMCU also acts as the Wi-Fi module that enables the user to control the SLCS using the smartphone by using the Blynk application. The Blynk dashboard is used to edit the Blynk controller and insert the auth token in Arduino IDE [5].

Table 1: Software and Hardware used in the SLCS.

Software	Hardware
Arduino IDE	Nodemcu
Blynk Dashboard	Photoresistor Module
Blynk Apps (Smartphone)	Passive Infrared (PIR) Sensor
-	5V Relay
-	AC Bulb

2.2 Methods

a) Project Block Diagram

To accomplish efficient lighting control, the deployed smart lighting control system (SLCS) for an office area combines many components. An LDR sensor monitors ambient light levels continuously, a PIR sensor detects occupancy, and a NodeMCU microcontroller processes sensor data. The system selects the proper lighting action based on this information, activating the AC bulb when light levels are low, and occupancy is detected. To save energy, the system turns off the lamp when there is enough light, or no occupancy is detected. Users can remotely administer the system using the Blynk remote control software, overriding automatic control and enabling personalized lighting settings. The SLCS assures optimized lighting management, promotes energy efficiency, and provides convenient remote-control capabilities when these components function together. Figure 1 shows a block diagram of the Smart Lighting Control System (SLCS).

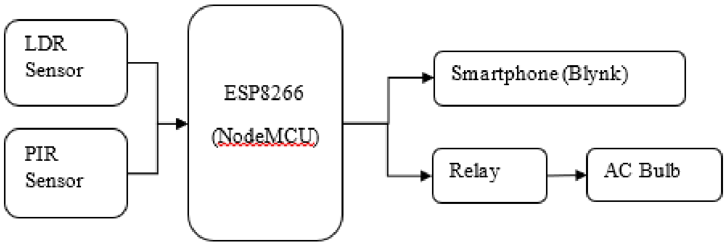

Figure 1: Block Diagram of the Smart Lighting Control System (SLCS)

In Figure 2, the illuminance parameter was set to 185 lux in the case study, and the photosensitive sensor detected the illuminance in the area. The Arduino Uno then processed this data to turn the bulb on or off as needed. If the illuminance was less than 185 lux, the bulb would stay on until the target amount of illuminance was reached. If the illuminance surpassed the predetermined value, the bulb would turn off. The photosensitive sensor allowed the lighting system to run autonomously. Furthermore, the smart lighting system may be managed via the Blynk app on a smartphone. This enabled customers to remotely operate the system, turning the light on and off with their smartphones if the sensor failed.

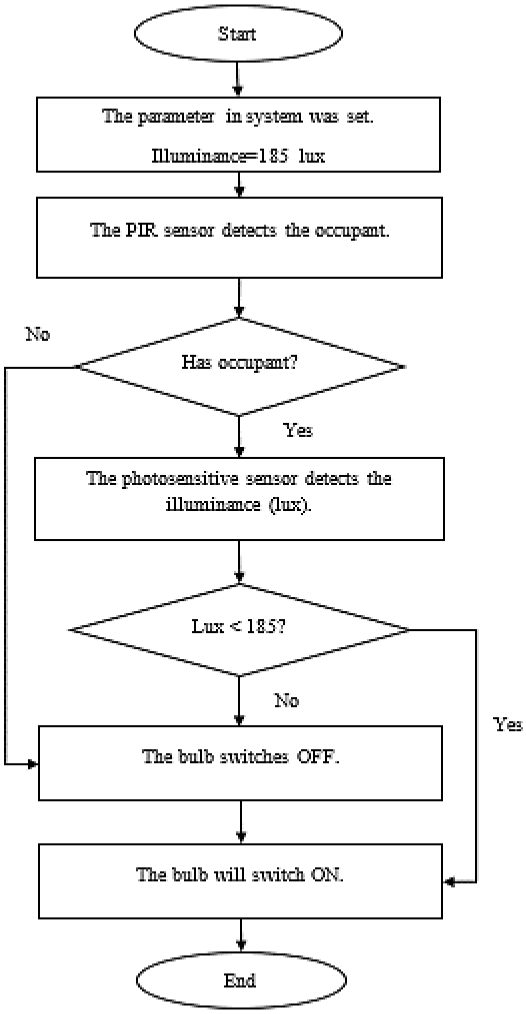

Figure 2: The Flowchart of the Smart Lighting Control System (SLCS)

3. Results and Discussion

The results and discussion section presents data and analysis of the study. This section can be organized based on the stated objectives, the chronological timeline, different case groupings, different experimental configurations, or any logical order as deemed appropriate.

3.1 Testing System

The data in Table 2 depicts the operation of a lighting system that includes a PIR sensor and a photoresistor module. Based on occupancy and illuminance levels, these sensors work together to optimize the operation of the AC bulb. The PIR sensor identifies inhabitants in the first scenario, while the photoresistor module assesses low illuminance (152 lux), causing the system to turn on the AC lamp for enough illumination. The PIR sensor detects occupants in the second situation, but the photoresistor module detects sufficient illuminance (185 lux), resulting in the AC light being turned off. In the third and fourth cases, when no occupants are identified and illumination conditions are inadequate or sufficient, the lighting system takes energy-efficient judgments to turn off or keep the AC bulb off.

Table 2: The results of the testing.

PIR Sensor	Photoresistor module	AC Bulb
Presence	152 lux	ON
Presence	185 lux	OFF
Presence	194 lux	OFF
Absence	157 lux	OFF
Absence	250 lux	OFF

3.2 Testing with Prototype

Testing the system's sensor effectiveness is critical for determining accuracy, and a prototype was utilized to examine performance under various conditions. In Condition A, the system responds to occupancy and daylight, turning off the light when the area is well-lit and occupied. Despite natural light, the bulb remains off in Condition B because there are no tenants. In the presence of inhabitants and darkness, Condition C causes the bulb to switch on. When there is no occupancy and no light, the bulb remains off in Condition D. Table 3 summarizes the results, which provide useful insights into the system's functioning and will aid in future upgrades to the smart lighting control system.

Table 3: Summary of testing for different conditions

Condition	Occupancy	Outside Prototype	Photoresistor Module	Bulb State
A (day)	Presence	Flashlight	Light detected	OFF
B (day)	Absence	Flashlight	Light detected	OFF
C (night)	Presence	No Flashlight	No light detected	ON
D (night)	Absence	No Flashlight	No light detected	OFF

3.3 Testing the Blynk App Control using Prototype.

The automatic ON/OFF AC bulb system described here is a practical and effective method for regulating the operation of a bulb based on various circumstances. It includes sensors such as a photoresistor module and a PIR sensor to detect movement and measure ambient light levels. Users can manage the bulb manually via the Blynk app connection, allowing for energy optimization and customization of the system's functionality via a combination of automatic and manual control modes.

When the user hits the ENABLE button, the system enters an automatic mode, utilizing the PIR sensor and photoresistor module to make intelligent decisions. If the PIR sensor detects movement and the ambient light level falls below a predetermined threshold, it switches on the AC bulb. If these requirements are not met, the light is turned off, promoting energy conservation. Furthermore, the system has a manual mode triggered by the disabled switch, allowing users to control the bulb's operation directly via the Blynk app. This adaptability allows customers to personalize the system by enabling them to enable or disable the automatic mode and effortlessly turn the light on and off. Overall, this controlled ON/OFF AC bulb system delivers excellent lighting management, promotes energy conservation, and gives convenience and customization possibilities for a seamless user experience. The pictures of this Blynk app testing are provided in Table 4.

Table 4: The testing of the Blynk app with Prototype

Button	Testing Picture	
ENABLE/DISABLE button.	 User push ENABLE button.	 User push DISABLE button.
ON/OFF button.	 User push ON button.	 User push OFF button.

4. Conclusion

In conclusion, the smart lighting control system (SLCS) development successfully used illuminance readings of 185 lux for a specific case study. The integration of the Blynk application allowed control of the SLCS through a smartphone, making management more convenient [5]. The hardware of the system effectively automated the turning on and off of AC lamps, resulting in lower power usage and a more comfortable working atmosphere for workers. In addition, the project included an analysis comparing the real circumstances in the case study to the SLCS prototype. The functioning of the SLCS was tested using several testing methodologies, offering significant insights into the system's performance and achievements. This analysis summarizes the system's tendencies and overall achievements.

Acknowledgement

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