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IoT-Driven Intelligent Automation for Energy Conservation in Lecture Halls

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Abstract

The use of energy during the current age is imperative in efficiently utilizing resources and conserving energy from wastage. Efficiency in using energy not only saves costs but also helps towards sustainable environments. The current work presents an IoT-based Energy Saving System for Lecture Rooms with a purpose of automating and maximizing utilization of electrical appliances such as light, fan, and air conditioner. The system incorporates Passive Infrared (PIR) sensors to sense the presence of human beings and to turn on/off the lights and fans automatically. The room temperature is also sensed by a temperature sensor and is displayed on an LED display, and the AC operates on pre-set temperature ranges to make it fully energy efficient. The system is combined with a real-time monitoring system wherein users are able to observe energy usage through an IoT-based interface. The proposed system will reduce wastage of energy because of manual operation and prolonged usage of electrical appliances in unoccupied lecture rooms. With the application of fuzzy logic-based dynamic control, the system conserves a significant amount of energy, approximately 41.96%, in comparison with normal manual operation. Apart from that, the system provides real-time electrical load consumption data through a mobile app to enable better monitoring and management of electrical loads. The results indicate that the IoT-based energy-saving system effectively saves energy and promotes environmental sustainability through a decrease in greenhouse gas emissions. The research contributes to the development of smart and intelligent power-saving systems for schools and similar environments, increasing energy efficiency and cost-effectiveness.

Keywords: *Energy saving system, Smart lecture hall, IoT, Sensors.*

1. Introduction

IoT stands for the Internet of Things, which refers to a network of connected smart devices that can easily communicate and exchange data with one another. The impact of it extends across a wide range of sectors, including healthcare [1-2] and smart wearable [3], as well as facilitating the development of intelligent cities [4], precision agriculture [5], and transportation systems of the future generation [6]. In addition to this, the Internet of Things improves shopping experiences [7] and propels innovation across all levels of industry [8]. The Internet of Things (IoT) has revolutionized our interactions with the surrounding environment through the seamless integration of technology into everyday life [9]. Conservation of energy has been a key challenge in the modern world because of increasing electricity requirements and growing environmental concerns related to energy usage. The Internet of Things (IoT) is still a viable solution to this challenge through the capability of intelligent and automated control systems. This paper introduces the design of an eco-friendly learning environment through an IoT-based system for energy saving in lecture rooms.The central aim of the project is the minimization of wastage of energy in schools through the introduction of sensors and automation technologies. The system operates using Passive Infrared (PIR) sensors to sense people's presence and automatically regulate electricity-consuming appliances including lights, fans, and air conditioners. Also, a temperature sensor is integrated to detect the room temperature and show it on an LED display, and an AC control system is utilized to regulate the air conditioning according to temperature fluctuations. Energy efficiency is of utmost importance in reducing the operational cost, limiting greenhouse gas emissions, and ensuring environmental sustainability. Manual conventional approaches towards control of electrical devices are vulnerable to unwarranted consumption of power through complacency of people. Scientific research has established that the use of fuzzy logic-based control systems and IoT automation has the capability to greatly minimize power usage. As an example, a comparative analysis of manual and fuzzy logic control approaches of air conditioning control found nearly 41.96% energy saving through dynamic temperature control. In addition, the integration of the IoT system offers real-time monitoring and control of electrical loads to remotely control energy usage. Use of sensors like PZEM, PIR, RTC, ESP32, Triac, and Optocoupler gives the project effective utilization of energy and avoiding electricity wastage. The system is automated to turn off lights and fans when the room is empty and regulate AC operation based on the room temperature level. The planned system not only saves energy but is also more convenient and safer in that it avoids the possibility of fire risks from discarded electric appliances. The technology is in line with worldwide efforts in supporting smart and green learning environments in schools, and thus a cleaner and more affordable future.

2. Background Study

The rapid development of the IoT has transformed energy consumption patterns, providing smart solutions to avoid wastage of electricity in public areas such as schools. Normal energy consumption in classrooms is plagued by issues since individuals tend to forget to switch off lights, fans, and air conditioners in vacant rooms. Manual control of power wastes energy, adds cost, and is environmentally unfriendly because it generates more greenhouse gases. As a result of this problem, many researchers applied various automation methods, using sensors and microcontrollers to monitor power consumption and conserve resources automatically in real time. IoT-based energy-efficient systems use technologies such as Passive Infrared (PIR) sensors to confirm whether a person is in the room, temperature sensors to confirm the weather, and microcontrollers such as ESP32 to switch on/off electric appliances. Through automation of sensors and fuzzy logic to make a decision, the systems save energy by regulating power based on the number of individuals in a room and temperature variations. Additionally, IoT-based systems provide real-time monitoring via mobile applications, which notify individuals in real time and provide remote control, making energy management and efficiency simple. Different studies have established that IoT-based automation successfully eliminates wastage of energy, with some systems saving more than 40% of energy as compared to normal manual control. The table 1 describes literature review of existing research on IoT-based smart energy management systems and provides findings, recommendations, and how they improve the current literature.

3. Design Methodology

The proposed design of the IoT-based Energy Saving System for Lecture Rooms aims to efficiently manage electrical energy consumption through the integration of various sensors (Table 1). The system operates in a sequential flow, as illustrated in the flowchart shown in Figure 1.

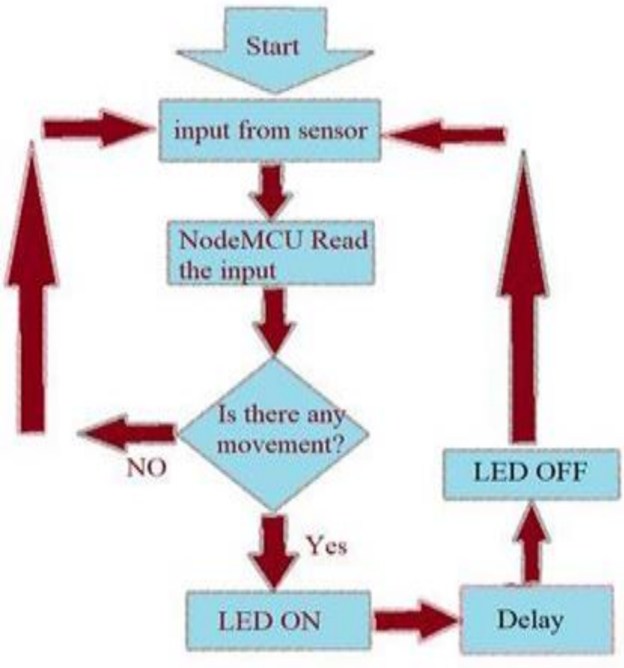

Figure 1 Flow Chart of the Proposed Design

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Table 1 Comparison of Previous Works

Ref.	Title of Page	Key Findings	Solution
[10]	Design of Smart and Intelligent Power Saving System for Indian Universities	Traditional systems waste power due to manual operation. Automated systems can reduce energy wastage.	Implemented a PIR sensor-based system to detect human presence and switch devices ON/OFF.
[11]	Energy Saving System using a PIR Sensor for Classroom Monitoring	PIR sensors can reduce unnecessary power usage in classrooms.	Designed an energy-saving system where PIR sensors detect motion and control lights and fans accordingly.
[12]	Intelligent Power Saving System using PIR Sensors	Office spaces waste electricity when unoccupied.	Implemented a centralized PIR sensor system to turn off computers and lights in offices when not in use.
[13]	Smart energy-efficient building automation with IoT-based sensing and control	IoT sensors help reduce energy consumption in smart buildings.	Proposed an integrated IoT-based system for automatic energy management
[14]	Adaptive lighting control using IR sensors for energy-efficient classrooms	IR sensors optimize lighting efficiency.	Designed an adaptive lighting control system.
[15]	IoT Enabled Intelligent Energy Management and Optimization Scheme with Controlling and Monitoring Approach in Modern Classroom Applications	PIR and IR sensors can improve energy efficiency.	Proposed an IoT-enabled classroom automation system.
[16]	Energy-efficient smart buildings: A case study on IoT-based occupancy monitoring	IoT-based monitoring significantly improves energy efficiency.	Conducted a case study using IoT-based smart building technology.
[17]	Energy Efficiency with IoT-Based Fuzzy Inference System for Room Temperature and Humidity Regulation	Fuzzy logic improves energy efficiency by optimizing air conditioner usage.	Developed an IoT-based system using fuzzy logic to dynamically adjust temperature settings.

The process begins with input from the PIR sensor, which detects human movement in the lecture room. The NodeMCU microcontroller reads the sensor input and determines whether any movement is detected. If no movement is detected, the system automatically turns off the LED lights and electrical appliances to conserve energy. However, if movement is detected, the system turns on the LED lights and other electrical devices. A delay mechanism is incorporated to prevent frequent switching and provide stable operation. The system continuously monitors the environment, displaying the room temperature on an LED display and controlling the AC based on the detected temperature. The ESP32 microcontroller facilitates real-time data analysis and communication with the Blynk application for remote monitoring and control. This intelligent automation system ensures energy efficiency, reduces power wastage, and contributes to a sustainable learning environment.

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3.1. Hardware Components

The study aims at developing an IoT-driven energy-efficient and power-saving system for the lecture hall. The system is based on PIR sensors for the detection of human beings and automatically controlling electric devices such as lights, fans, and air conditioners. The temperature sensor is utilized to measure the temperature of the lecture room and is displayed on an LED display, and the AC mode is regulated by an air conditioning control system based on the variation in temperature. Given below is a step-by-step description of every element:

3.2.Arduino Nano

The platform that allows for designing electronics is the most popular, the open-source Arduino Nano (Figure 2). As in all other cases, it combines the hardware and software components into one application that is easy to use. The Arduino Nano is a microcontroller board that uses the ATmega328p chip. It functions likewise to the Arduino UNO but is small. The Arduino Nano is also compatible, versatile, and well-fixed to use with breadboards.

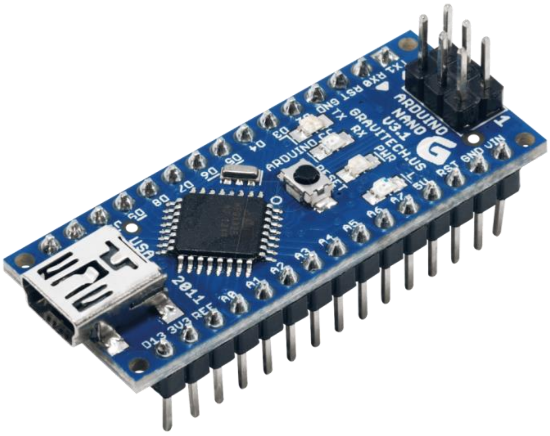

Figure 2 **Arduino Nano Board**

3.3.Node MCU (ESP8266)

NodeMCU is an open-source Internet of Things development board, which has been created using the ESP8266 Wi-Fi chip are illustrated in Figure 3. NodeMCU offers microcontroller devices a means of connection to Wi-Fi networks along with access to cloud servers. NodeMCU has GPIO pins, ADC, and UART interfaces and is therefore the perfect device to assist in accommodating sensors and data transfer. Due to low power usage as well as high-speed processing, it is best suited for IoT.

3.4.PIR Sensor

The PIR sensor can sense infrared radiation emitted by human bodies. It is commonly utilized in motion detectors. It sends a message to the microcontroller whenever a human crosses its field of action, which can be utilized to activate functions such as lighting up lights or security systems. Figure 4 illustrated the PIR sensor.

Figure 3 **Node MCU (ESP8266) [9]**

Figure 4 **HC-SR04 Sensor**

3.5.Ultrasonic Sensor

DHT22 is a digital temperature and humidity sensor which is illustrated in Figure 5. It senses the temperature and humidity of the surrounding environment and sends them to the microcontroller for analysis. It can find extensive applications in environment monitoring systems

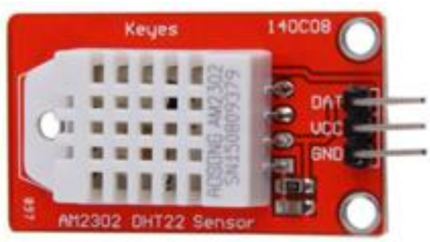

Figure 5 **DHT22 Digital Temperature and Humidity Sensor**

3.6.Ultrasonic Sensor

Ultrasonic sensing, HC-SR04 illustrated in Figure 6, element measure distance and detect objective by emitting wave and listen for the replication. No physical contact is required. Depending on the sensor and the aim's characteristics, the effective range of these sensors in aura can change from simply a few centimeters to respective meters.

Figure 6 HC-SR04 Sensor Module

3.7.Infrared Sensors

Infrared sensors is illustrated in Figure 7, are used in utilized for proximity detection and object detection. These sensors can be damaged by high-pitched temperatures. They react faster and more accurately than heat or smoke detectors due to their specialized mechanism for detect flames.

Figure 7 KY-026 IR Sensor Module [8]

3.8.LDR Photo Resistor Sensor Module

LDR means light-dependent resistor that shows varied resistance with more intensity of light. LDR (shown in Figure 8) is used in automatic lighting control in circuits so that lights turn on or turn off depending upon the light intensity of the vicinity around.

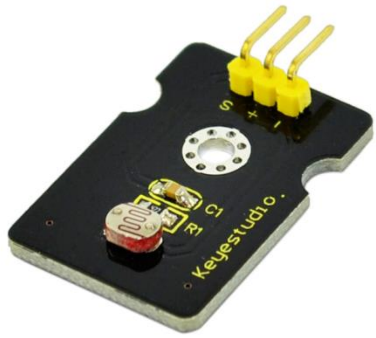

Figure 8 KY-018 LDR Photo Resistor Sensor Module

3.9.Relay Module

A relay driver circuit is a circuit that acts as an interface between high power devices and the microcontroller. It supplies low voltage levels from the microcontroller to drive high voltage devices such as bulbs, fans, or motors. The relay acts as an electrical switch by opening or closing the circuit.

Figure 9 Relay Module

3.10.Software Development

The features of speech and functionality of the target system are outlined in the software package specially. At the same meter, computer measures quantify and make up the software's unlike characteristic. Software metrics allow for measuring various aspects of computer software mental process and products. These measurements are essential for technology, as they help wield the software package ontogeny process and ensure the last Cartesian product sustain high-pitched quality.

Arduino IDE software: The Arduino Software (IDE) runs seamlessly on Windows, macOS, and

Linux, making coding and uploading a breeze. Crafted in Java and inspired by Processing and other open-source tools, its intuitive environment empowers creators to bring their ideas to life effortlessly. IDE is usable with any Arduino board, or we can also use Intrnet source for show the collecting data by which we can enhance the safety system in future using the data.

Blynk: Blynk is a cutting-edge platform crafted for IoT enthusiasts, offering sleek iOS and Android apps that seamlessly connect with microcontrollers like Arduino, Raspberry Pi, and more. With Blynk, we can effortlessly control and monitor your devices over the internet. Blynk set aside distant control of computer hardware, displays detector data, computer memory datum, visualizes data point, and performs many other tasks. The three primal parts of Blynk are:

- **Blynk App:** This component part allows you to make amazing interface for systems by using various types of widgets.
- **Blynk Server:** This component enables communication between smart phones and hardware. For example, users can connect through the shared Blynk cloud or set up their own private Blynk server locally. The Blynk Server is open-source and can manage many devices.
- **Blynk libraries:** This component enables hardware platforms to communicate with the host and handle all incoming and forthcoming commands. For example, when a user crusades a clit in the Blynk app, the substance is gotten off to the Blynk Cloud and chop-chop make the drug user's hardware. The reverse process also takes only an abbreviated consequence to complete.

4. Block Diagram of the Proposed Design and Working

Algorithm of the proposed work as follow:

Step I: Power on the Arduino Nano.
Step II: Initialize the PIR sensor, Temperature sensor, IR sensor, LDR sensor.
Step III: Establishing IoT connection (connect via ESP8266/Wi-Fi module).
Step IV: Connection validation.
Step V: Object detection and System triggering.
Step VI: If PIR sensor human detect. LED and Fans turn ON.
Step VII: And in the last all the data are collected at cloud.

The central controller of the system is an Arduino Nano, as illustrated in block diagram of the presented design illustrate in Figure 10.

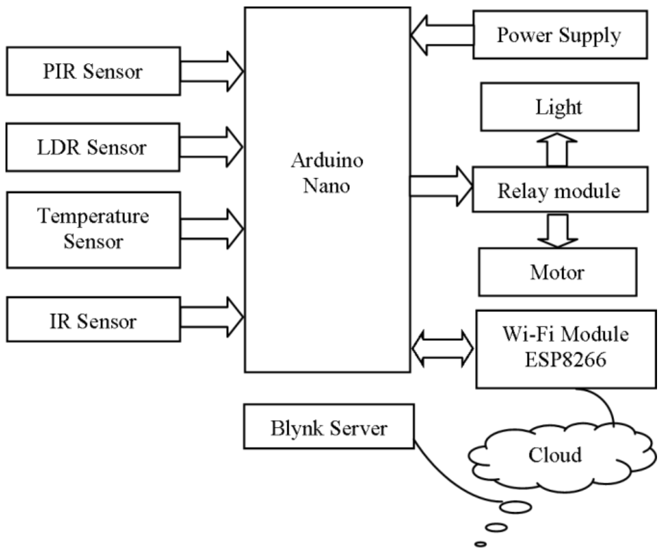

Figure 10 Block Diagram of the Proposed Design Solution

5. Results and Discussion

The IoT-based Energy Saving System for Lecture Rooms was tested under various conditions to assess its effectiveness in energy conservation, automation efficiency, and system reliability. The results demonstrated significant improvements in energy management by integrating PIR sensors, temperature sensors, and IR sensors with cloud-based IoT technology. The PIR sensors efficiently detected human presence within a range of 3-5 meters, ensuring that electrical appliances such as lights and fans were activated only when the classroom was occupied. Similarly, the temperature sensor provided accurate readings, allowing dynamic control of the HVAC system, which contributed to optimized energy consumption. The IR sensor, used for student entry detection, proved to be reliable in tracking occupancy changes, further enhancing the automation of energy-saving measures. In terms of energy efficiency, the system successfully reduced overall power consumption. The automatic control of lights and fans resulted in an energy reduction of 25-30%, as the system ensured that these appliances were turned off in unoccupied rooms. Furthermore, temperature-based HVAC control led to an energy saving of approximately 41.96%, as the system dynamically adjusted air conditioning usage based on real-time room conditions. The IoT-based monitoring system also contributed to energy conservation by preventing unnecessary power usage, leading to a reduction of 0.085 kWh per hour through PIR-controlled operations. The integration of cloud-based IoT technology played a crucial role in enhancing the system's functionality. Real-time data monitoring allowed for remote access and decision-making, enabling users to track power usage and make adjustments via an IoT dashboard. The system successfully transmitted sensor data to a cloud platform, where energy consumption patterns were analyzed to detect anomalies and optimize usage. Through platforms like Blynk, users were able to monitor real-time power consumption, receive alerts, and control appliances remotely, ensuring efficient and automated classroom management. In cases of abnormal conditions such as overheating or unauthorized occupancy, the system generated alerts and took necessary actions, further improving safety and energy efficiency. When compared to conventional energy management methods, the proposed system demonstrated higher accuracy, faster response times, and reduced operational costs. The automation of classroom appliances based on real-time occupancy detection significantly improved energy utilization, reducing human dependency and minimizing wastage. The results clearly indicate that IoT-based smart classroom energy management can enhance sustainability, improve monitoring efficiency, and contribute to a more energy-conscious environment in educational institutions. The implementation of such a system represents a practical step toward modernizing classrooms with smart and energy-efficient solutions, ensuring a balance between technological advancement and energy conservation.

Conclusion

The system in use here utilizes IoT-based technology to the fullest via the usage of microcontrollers and sensors to sense and automate the environmental parameters. Hardware devices like PIR sensor, Ultrasonic sensor, IR sensor, Temperature sensor, LDR sensor, and Relay Driver Circuit individually sense motion, light level, and temperature difference and facilitate real-time and effective decision-making. The role of the system to accept and transfer data in wireless mode is that which makes it very effective in industry automation as well as in home automation. The role of NodeMCU to utilize it and implement enhanced connectivity by Wi-Fi and Arduino to continuously render accurate control of sensors is what makes it efficient. The system not only lessens the level of human effort required but utilizes maximum energy uptake. Future developments like the combination of machine learning algorithms and cloud storage will enhance it further to be even more efficient and scalable. The research provides a good basis for the development of more intelligent and adaptive IoT-based systems

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