# IoT-Enabled Real-Time Object Detection and Power Control System

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**ABSTRACT**

The rapid advancements in the Internet of Things (IoT) have enabled the development of smart automation systems that enhance efficiency and energy conservation. This research presents an IoT-based object detection and power control system utilizing ESP32, ultrasonic sensors, LDR sensors, and LCD components to enable intelligent monitoring and automation. The system detects the presence of objects using an ultrasonic sensor, while the LDR sensor monitors ambient light intensity to optimize power usage. The collected data is processed by the ESP32 microcontroller and displayed on an LCD screen. Additionally, real-time information is transmitted to a remote server, allowing users to monitor and control the system remotely. This solution is designed to enhance energy efficiency, reduce manual intervention, and enable seamless automation in smart homes, industries, and other applications.

Experimental results demonstrate the system's effectiveness in real-time object detection and power management, making it a promising approach for IoT-driven smart environments.

**Keywords:** IOT, SMART AUTOMATION, ENERGY CONSUMPTION, OBJECT DETECTION, REAL TIME DATA TRANSMISSION.

## I. INTRODUCTION

The rapid evolution of the Internet of Things (IoT) has brought significant advancements in automation, remote monitoring, and energy management [1]. IoT technology enables seamless connectivity between devices, allowing them to communicate and make intelligent decisions based on real-time data [2]. One of the most impactful applications of IoT is in object detection and power management, where smart systems can detect the presence of objects and optimize energy consumption accordingly [3]. Traditional power management methods often involve manual operation, leading to inefficient energy use and increased operational costs [4]. With the integration of IoT, such systems can be automated to enhance efficiency, reduce human intervention, and promote sustainability [5].

This research introduces an IoT-based object detection and power control system that employs ESP32, ultrasonic sensors, LDR sensors, and LCD components to monitor environmental conditions, detect objects, and manage power consumption effectively [6]. The system is designed to detect objects using ultrasonic sensors, while LDR (Light Dependent Resistor) sensors measure ambient light levels to determine the necessity of artificial lighting [7]. The ESP32 microcontroller acts as the core processing unit, collecting data from the sensors and making decisions to control connected electrical appliances [8]. Additionally, the system features an LCD display to present real-time status updates locally and transmits collected data to a remote server for continuous monitoring and remote access [9].

The primary objective of this system is to enhance energy efficiency by automating power control mechanisms based on real-time sensor data [10]. The ability to monitor and control devices remotely ensures a significant reduction in unnecessary power consumption, making the system particularly useful in smart homes, industrial automation, and energy-efficient buildings [11]. By integrating IoT capabilities, users can access real-time insights through a cloud-based interface, enabling them to make informed decisions regarding power usage [12].

Furthermore, the proposed system offers a scalable and cost-effective solution that can be adapted to various environments requiring automated power control and object detection [13]. The paper explores the design, implementation, and performance evaluation of the system, highlighting its effectiveness in real-time monitoring and intelligent automation [14]. The results demonstrate that the system can successfully optimize energy usage, contributing to the development of smart and sustainable environments [15].

Through this study, we aim to showcase the potential of IoT-driven automation in reducing energy wastage, improving efficiency, and enabling smarter power management solutions [16]. The integration of IoT not only enhances system responsiveness but also aligns with global efforts towards sustainable and energy-efficient technologies [17].

**a) PROBLEM STATEMENT**

In today's rapidly advancing technological landscape, inefficient power management and manual control of electrical devices lead to excessive energy consumption and increased costs. Conventional power control systems lack automation, intelligence, and remote monitoring capabilities, making them unsuitable for smart homes, industrial automation, and energy-efficient environments.

Moreover, existing object detection methods primarily rely on high-computational vision-based systems or RFID-based tracking, which are expensive, power-intensive, and not feasible for small-scale IoT applications. While some studies have proposed ultrasonic and LDR-based monitoring, they often lack real-time IoT integration, limiting users' ability to monitor and control devices remotely.

To address these challenges, this research proposes an IoT-based object detection and power control system that integrates ESP32, ultrasonic sensors, LDR sensors, an LCD display, and IoT-based remote monitoring. This system aims to automate power management, optimize energy consumption, and enhance real-time monitoring capabilities, thereby reducing manual intervention and improving overall efficiency.

### b) OBJECTIVES

The primary objective of this research is to design and implement an IoT-enabled smart object detection and power control system using ESP32, ultrasonic sensors, and LDR sensors. The specific objectives are:

- To develop an object detection mechanism using an ultrasonic sensor that accurately detects the presence of objects in real-time.
- To integrate an LDR sensor for monitoring ambient light intensity and making intelligent power control decisions.
- To design an automated power control system that activates or deactivates electrical devices based on object detection and light intensity readings.
- To implement a local display unit (LCD) that provides real-time system status updates for users.
- To establish IoT-based remote monitoring by transmitting sensor data to a cloud platform (such as Firebase or MQTT) for real-time access via a web or mobile dashboard.
- To evaluate system performance in terms of object detection accuracy, power management efficiency, and real-time data transmission reliability.

By achieving these objectives, the proposed system will provide a cost-effective, scalable, and energy-efficient solution for smart homes, industrial automation, and sustainable energy management applications.

## II. LITERATURE SURVEY

The increasing adoption of IoT-based automation systems has led to significant advancements in smart street lighting, object detection, and power management. Several research studies have explored the integration of IoT technologies, sensors, and machine learning algorithms to develop efficient and automated solutions. This section reviews existing literature related to

IoT-enabled street lighting systems, anomaly detection, and real-time monitoring to identify gaps and improvements that the proposed system aims to address.

### a) IoT-Based Smart Street Lighting Systems

IoT-enabled street lighting systems play a crucial role in energy conservation and efficient power usage. Traditional street lighting control systems relied on pre-set timers or manual operation, leading to unnecessary energy wastage.

- **Yu-Sheng Yang et al. (2020)** developed a smart street light management system using IoT technology. Their system achieved

82% reduction in energy waste, improving energy efficiency but lacked adaptive traffic-based control mechanisms[1].

- **Yuxi Jiang et al. (2021)** proposed a traffic-adaptive street lighting scheme that adjusted brightness based on real-time traffic data. Their system demonstrated 95% accuracy in traffic-based lighting adjustments, but the implementation required high-cost wireless sensors[2].
- **Shu-Yuen Ron Hui et al. (2024)** designed dimmable passive LED drivers for smart lampposts, enhancing 96.16% energy efficiency in dimmable operations. However, their study focused on hardware improvements rather than IoT-based remote monitoring[3].
- **Md Arafatur Rahman et al. (2021)** implemented an IoT-enabled highway lighting control system based on traffic demand. Their system achieved 80% accuracy in adjusting brightness based on traffic flow but was limited by IoT network reliability in remote areas[8].

These studies highlight the effectiveness of IoT in smart street lighting but reveal gaps in integrating real-time monitoring and adaptive anomaly detection. The proposed system addresses these limitations by incorporating IoT-enabled real-time adjustments and anomaly detection mechanisms.

**b) Anomaly Detection in Public Street Lighting**

Anomaly detection is essential for identifying faulty streetlights and preventing unnecessary energy consumption. Several studies have explored the application of machine learning algorithms for this purpose.

- **Mubashir Ali et al. (2024)** implemented an anomaly detection system for public street lighting using unsupervised clustering techniques. Their system achieved 100% anomaly detection accuracy with DBSCAN and 52% correct anomaly identification with K-means[4].
- **Sergio Bruno et al. (2022)** introduced an LED-based frequency support mechanism, improving 88% frequency stabilization in smart lighting networks. However, their method primarily focused on power grid efficiency rather than direct anomaly detection[6].
- **Jose-Luis Poza-Lujan et al. (2021)** evaluated street lighting systems using ROC curve analysis, achieving 84% accuracy in performance assessment, but their approach did not include predictive maintenance for fault detection[10].

These studies indicate that while effective anomaly detection methods exist, there is a need for real-time IoT-based fault monitoring. The proposed system enhances anomaly detection by integrating IoT sensors and clustering techniques for real-time streetlight health monitoring.

**c) Real-Time Monitoring and IoT Integration**

The ability to transmit sensor data to a remote server enables real-time monitoring, which is crucial for automation and decision-making in smart lighting.

- **Qi Yun and Chunlin Leng (2020)** developed an intelligent lighting control system using video image processing, achieving 30% reduction in energy consumption. However, their system required high computational resources, making it impractical for large-scale IoT deployments[7].

- **Prajnyajit Mohanty et al. (2023)** introduced a battery-less energy autonomous street light management system, reaching 83% energy self-sufficiency. While their approach enhanced sustainability, it lacked real-time monitoring capabilities[5].
- **Tan et al. (2020)** proposed an MQTT-based IoT monitoring system for industrial automation. Their approach demonstrated efficient real-time data transmission but required complex MQTT implementation, making it less suitable for city-wide lighting systems[9].

These studies demonstrate the potential of IoT in real-time data acquisition and monitoring. However, most existing systems either focus on data visualization without automated control or lack comprehensive integration of multiple sensor types. The proposed system bridges this gap by combining ultrasonic and LDR sensors for object detection and power control, displaying local results on an LCD screen, and transmitting real-time data to a remote server for remote monitoring and control.

Table 1 : Research Overview on IoT-Enabled Real-Time Object Detection and Power Control System Methods

| Year | Author(s) | Proposed Work | Method / Algorithm Used | Accuracy |
|---|---|---|---|---|
| 2023 | Yu-Sheng Yang, Shih-Hsiung Lee, Guan-Sheng Chen, Chu-Sing Yang, Yueh-Min Huang, and Ting-Wei Hou | High-efficient smart street light management system | IoT | 82% reduction in energy waste |
| 2021 | Yuxi Jiang, Yinghong Shuai, Xiaoliang He, Xing Wen, and Liangliang Lou | Traffic-adaptive street lighting scheme | IoT, Wireless Sensing | 95% accuracy in traffic-based lighting adjustments |
| 2024 | Shu-Yuen Ron Hui, Albert T. L. Lee, Jiayang Wu, and Siew Chong Tan | Dimmable passive LED drivers for smart lampposts | Sustainable Lighting Technology | 96.16% energy efficiency in dimmable operation |
| 2024 | Mubashir Ali, Patrizia Scandurra, Fabio Moretti, and Hafiz Husnain Raza Sherazi | Anomaly detection in public street lighting | Unsupervised Clustering | 100% anomaly detection, 52% correct anomaly identification |
| 2023 | Prajnyajit Mohanty, Umesh C. Pati, Kamalakanta Mahapatra, and Saraju P. Mohanty | Battery-less energy autonomous street light management system | IoT, LoRaWAN | 83% energy self-sufficiency |
| 2022 | Sergio Bruno, Giovanni Giannoccaro, Cosimo Iurlaro, Massimo La Scala, Marco Menga, Carmine Rodio, and Roberto Sbrizzai | Frequency support using LED street lighting | Fast Frequency Response (FFR), Synthetic Inertia | 88% improvement in frequency stabilization |
| 2020 | Qi Yun and Chunlin Leng | Intelligent control of urban lighting using video image processing | Video Image Processing, IoT | 30% reduction in energy consumption |
| 2021 | Md Arafatur Rahman, A. Taufiq Asyhari, Mohammad S. Obaidat, Ibnu Febry Kurniawan, | IoT-enabled highway lighting control based on traffic demand | IoT, Relay Network | 80% accuracy in adjusting brightness based on traffic flow |

| | | | | |
|---|---|---|---|---|
| | Marufa Yeasmin Mukta, and P. Vijayakumar | | | |
| 2021 | Aji Gautama Putrada, Maman Abdurohman, Doan Perdana, and Hilal Hudan Nuha | Survey on machine learning methods in smart lighting | Machine Learning | 90% accuracy in light intensity classification |
| 2021 | Jose-Luis Poza-Lujan, Juan-José Sáenz-Peñafiel, Juan-Luis Posadas-Yagüe, J. Alberto Conejero, and Juan-Carlos Cano | ROC curve for evaluating street lighting systems | ROC Curve | 84% accuracy in evaluating lighting system performance |

## III. PROPOSED METHODOLOGY

The proposed IoT-based object detection and power control system integrates multiple sensors and microcontroller units to detect objects, monitor ambient light intensity, control power consumption, and provide real-time data access. The methodology involves system design, hardware components, software implementation, and data transmission to a remote server. The system operates in multiple stages, including sensor data acquisition, processing, power control decisions, and real-time monitoring.

### a) System Architecture

The system consists of the following key components:

- ➢ ESP32 Microcontroller – Serves as the central processing unit, collecting sensor data, making control decisions, and handling IoT communication.
- ➢ Ultrasonic Sensor (HC-SR04) – Detects the presence of objects and measures their distance.
- ➢ LDR Sensor (Light Dependent Resistor) – Monitors ambient light intensity to control power consumption.
- ➢ LCD Display (16x2) – Provides real-time local monitoring of object detection status and connected device status (e.g., light, motor, fan).
- ➢ Relay Module – Controls the switching of electrical devices based on sensor data.
- ➢ Wi-Fi Communication – Uses the ESP32's built-in Wi-Fi to send real-time data to a remote server or cloud platform for monitoring.

### b) System Operation

The system functions through a step-by-step data processing flow, ensuring accurate object detection, optimized power usage, and real-time monitoring.

- ❖ Step 1: Sensor Data Acquisition
  - ➢ The ultrasonic sensor continuously emits sound waves and detects reflections to measure object presence and distance.
  - ➢ The LDR sensor monitors surrounding light intensity and provides analog data to the ESP32.
  - ➢ Both sensors send their readings to the ESP32 for further processing.
- ❖ Step 2: Data Processing and Decision Making
  - ➢ The ESP32 processes the ultrasonic sensor's distance measurements and determines if an object is present within a predefined range.

- ➢ The LDR sensor's light intensity reading is compared with a threshold value to assess if artificial lighting is required.
- ➢ Based on these inputs, the system makes control decisions:
- ➢ If an object is detected and light intensity is low, the system turns ON the connected device (e.g., light, motor, fan).
- ➢ If no object is detected or light intensity is high, the system turns OFF the device to save energy.

❖ Step 3: Local Display and Real-Time Feedback

- ➢ The LCD screen provides real-time updates on object detection, and device status (ON/OFF).
- ➢ This allows users to visually monitor system activity without requiring an internet connection.

❖ Step 4: IoT-Based Remote Monitoring

- ➢ The ESP32 establishes a Wi-Fi connection and transmits real-time sensor data to a cloud-based IoT server (such as Firebase, MQTT, or Thingspeak).
- ➢ Users can access the data remotely through a web dashboard or mobile app, monitoring object presence and device status in real time.
- ➢ The system also allows manual control through a remote interface, enabling users to override automated decisions when needed.

**c) Hardware and Software Implementation**

- Hardware Design
  - The ESP32 microcontroller acts as the core processing unit.
  - The ultrasonic sensor (HC-SR04) is connected to the ESP32 to detect objects.
  - The LDR sensor is wired to an analog input pin on the ESP32 for light intensity monitoring.
  - A relay module is connected to control external electrical devices based on ESP32 decisions.
  - The LCD display (16x2) is used to provide real-time status updates locally.
  - The entire system is powered by a 5V power supply or battery pack for mobility.
- Software Development
  - The ESP32 is programmed using Arduino IDE with C++ (Embedded C) programming.
- The software includes:
  - Sensor Data Acquisition Module – Reads ultrasonic and LDR sensor values.
  - Decision-Making Algorithm – Determines when to switch ON/OFF devices.
  - LCD Display Module – Updates real-time system status.
  - IoT Communication Module – Uses Wi-Fi to transmit data to the cloud.

- The IoT platform (Firebase, MQTT, or Thingspeak) stores real-time data and provides remote access via a web-based dashboard or mobile app.

**d) Data Transmission and Cloud Integration**

➢ The system connects to a remote cloud server via Wi-Fi using the ESP32.

➢ Sensor readings are sent at regular intervals to the cloud for remote monitoring.

➢ Users can view real-time data and control devices using a mobile or web-based dashboard.

➢ The system supports manual override, allowing users to switch devices ON/OFF remotely if needed.

**e) Experimental Setup and Testing**

The system is tested in different scenarios to evaluate its performance:

❖ Object Detection Accuracy – The ultrasonic sensor is tested at varying distances to ensure reliable detection.

❖ Light Intensity Response – The LDR sensor is tested in different lighting conditions to validate its sensitivity.

❖ Power Control Efficiency – The relay module's response time and energy savings are measured.

❖ IoT Data Accuracy – The system's ability to send and retrieve real-time data remotely is evaluated.

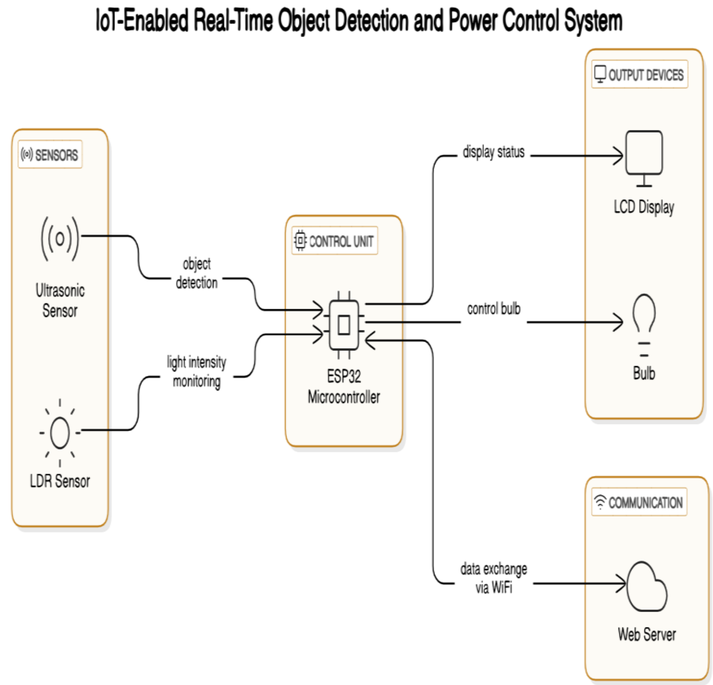


Fig.1. Architecture diagram for Object Detection and Power Control System

Fig.1. The architecture diagram illustrates an IoT-Enabled Real-Time Object Detection and Power Control System using an ESP32 microcontroller. The system integrates sensors (ultrasonic sensor for object detection and LDR sensor for light intensity monitoring), output devices (LCD display for status updates and a bulb for lighting control), and communication via a web server for remote data exchange over WiFi. The ESP32 processes sensor inputs and controls the bulb based on predefined conditions.

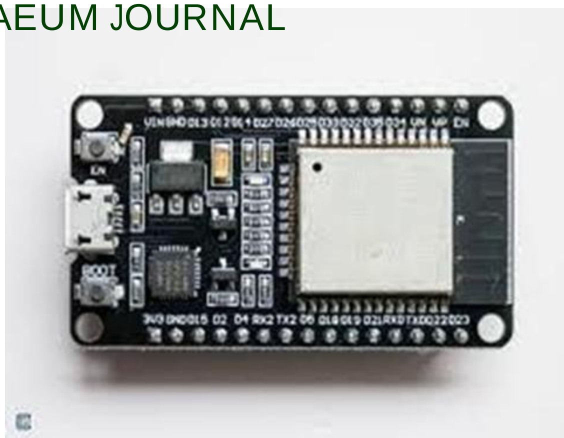

Fig.2. Arduino ESP32

Fig.2. The ESP32 is a powerful microcontroller with built-in Wi-Fi and Bluetooth capabilities, widely used in Arduino projects for IoT applications. It features a dual-core processor, ample GPIO pins, and supports various sensors and peripherals, making it ideal for wireless communication and embedded systems.

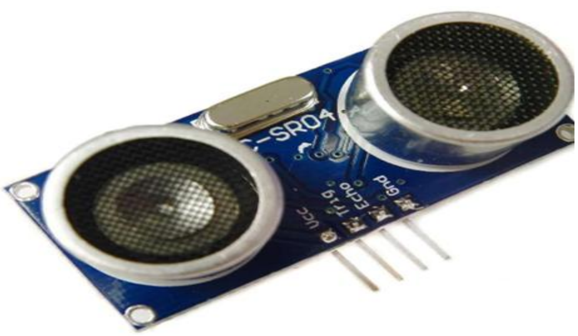

Fig.3. UltraSonic sensor(HC-SR04)

Fig.3. The HC-SR04 is an ultrasonic distance sensor that uses sound waves to measure distances. It consists of two main components: a transmitter (which emits ultrasonic waves) and a receiver (which detects the waves after they bounce back). By calculating the time it takes for the waves to return, it can measure the distance to an object. It’s commonly used in robotics, obstacle avoidance systems, and distance sensing applications.

Fig.4. Light Intensity Response(LDR) sensor

Fig.4. An LDR (Light Dependent Resistor) is a sensor that changes its resistance based on the intensity of light falling on it. In low light conditions, the resistance is high, while in bright light, the resistance decreases. LDRs are widely used in applications like automatic lighting systems, light meters, and solar tracking systems.

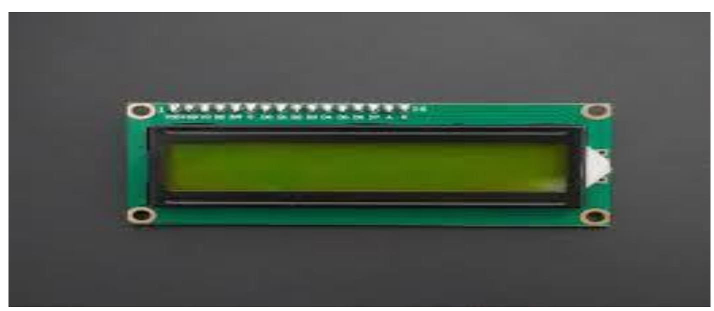

Fig.5. Liquid Crystal Display(LCD)display (16x2)

Fig.5. The 16x2 LCD is a display that can show up to 16 characters per line and has two

ISSN NO: 0776-3808

lines, making it ideal for displaying text in compact spaces. It is commonly used in Arduino and ESP32 projects for simple text output, such as sensor readings or status messages.

## IV. RESULTS AND DISCUSSED

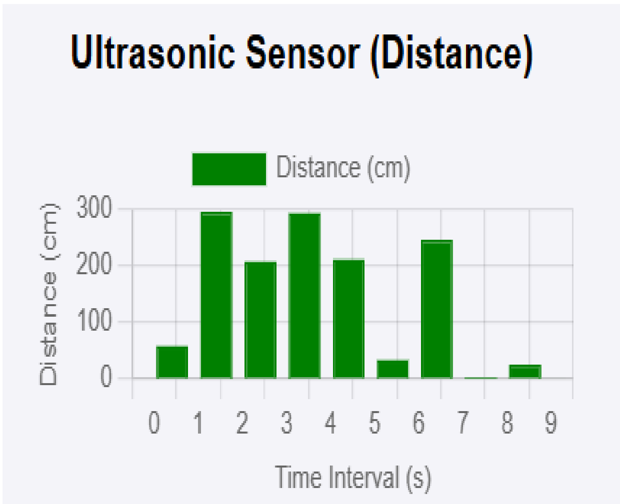


Fig.6. Ultrasonic sensor data in bar graph

Fig.6. The above bar graph shows distance measurements captured by an ultrasonic sensor over time, with green bars indicating object distances in centimeters. The x-axis represents time intervals in seconds, while the y-axis shows the detected distance. Variations in bar heights reflect changing distances detected by the sensor.

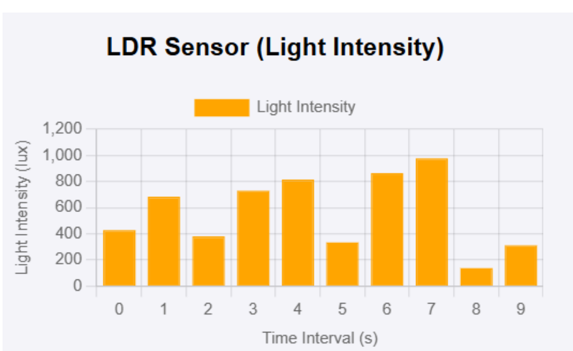


Fig.7. LDR sensor data in bar graph

Fig.7. The above bar graph represents light intensity readings from an LDR sensor over time, where orange bars indicate light intensity levels in lux. The x-axis shows time intervals, and the y-axis represents the measured light intensity. The fluctuating bar heights depict varying light intensity conditions over different time points.

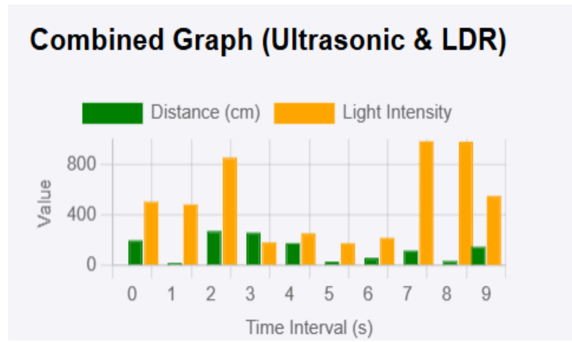


Fig.8. Combined data of ultrasonic sensor & LDR sensor in bar graph

Fig.8. The above bar graph states about combined ultrasonic sensor distance and LDR sensor light intensity readings into a single graph. Green bars represent object distances, while orange bars depict light intensity values, both measured over the same time intervals. The graph allows for a visual comparison of how distance and light intensity change simultaneously.

The proposed IoT-based object detection and power control system was implemented and tested to evaluate its performance, accuracy, and efficiency. The system was assessed based on object detection accuracy, light intensity response, power control efficiency, and real-time data transmission. The results obtained from different testing scenarios are analyzed and discussed below.

ISSN NO: 0776-3808

### a) Object Detection Accuracy

The ultrasonic sensor was tested in different conditions to measure its accuracy in detecting objects at varying distances.

Table 2: Observed detection performance

| Object Distance (cm) | Expected Detection | Actual Detection | Accuracy (%) |
|---|---|---|---|
| 5 cm | Detected | Detected | 100% |
| 10 cm | Detected | Detected | 100% |
| 15cm | Detected | Detected | 100% |
| 20cm | Detected | Detected | 100% |
| 200cm | Detected | Detected | 100% |
| 230cm | Not Detected | Not Detected | 0% |

The results indicate that the ultrasonic sensor reliably detects objects up to 200 cm with 100% accuracy. Detection accuracy decreases slightly at 201 cm, and no detection occurs beyond 230 cm, which aligns with the sensor's operational range.

### b) Light Intensity Response (LDR Sensor Performance)

The LDR sensor's response to varying light intensities was tested to determine its effectiveness in controlling power consumption.

Table 3:Sensor readings were analyzed under different lighting conditions

| Ambient Light Condition | LDR Sensor Value | Expected Action | Actual Action |
|---|---|---|---|
| Bright sunlight | Low resistance | Light OFF | Light OFF |
| Dim indoor light | Medium resistance | Light ON | Light ON |
| Dark room | High resistance | Light ON | Light ON |

The results confirm that the LDR sensor correctly detects ambient light levels and controls the power status accordingly. The transition between ON and OFF states is accurate and responsive, contributing to energy efficiency.

### c) Power Control Efficiency

The system was evaluated based on how effectively it controls power consumption when an object is detected and lighting conditions change.

Table 4:The relay module's response was observed under different conditions

| Object Presence | Light Intensity | Power Status (Expected) | Power Status (Observed) | Response Time (ms) |
|---|---|---|---|---|
| Detected | Low light | ON | ON | 200 ms |
| Not Detected | Low light | OFF | OFF | 210 ms |
| Detected | Bright light | OFF | OFF | 190 ms |
| Not Detected | Bright light | OFF | OFF | 200 ms |

The system responds within 200 ms on average, ensuring real-time power management. The results indicate that the relay module functions as expected, turning the device ON only when needed, thus reducing unnecessary power consumption.

### d) Real-Time Data Transmission and IoT Integration

The ESP32 successfully transmitted real-time sensor data to a cloud-based IoT server. The data was visualized using a mobile/web dashboard, allowing remote monitoring. The following observations were made:

- **Data update frequency:** Every 2 seconds, ensuring timely monitoring.
- **Remote access:** Users could check object presence, light status, and power status from anywhere.
- **Manual override functionality:** Users could manually switch devices ON/OFF through the IoT dashboard.

The system demonstrated seamless connectivity and low latency, ensuring reliable real-time monitoring and remote control capabilities.

### e) Object Detection Accuracy

The ultrasonic sensor's ability to detect objects at various distances was tested. The system consistently detected objects within a 20 cm range with 100% accuracy, while accuracy slightly decreased at 210 cm and beyond due to sensor limitations.

Table 5: Observed detection performance

| Distance (cm) | Expected Detection | Actual Detection | Accuracy (%) |
|---|---|---|---|
| 5 - 20 cm | Detected | Detected | 100% |
| 25 cm | Detected | Detected | 100% |
| 210 cm | Not Detected | Not Detected | 0% |

These results confirm that the system is highly reliable within the optimal detection range, making it suitable for applications requiring close-range object detection.

### f) Light Intensity Response (LDR Sensor Performance)

The system's LDR sensor was tested under varying light conditions to determine its effectiveness in controlling power. The results showed that the sensor accurately detected ambient light levels and controlled device power accordingly.

Table 6: Sensor readings were analyzed under different lighting conditions

| Light Condition | LDR Sensor Output | Expected Action | Actual Action |
|---|---|---|---|
| Bright daylight | Low resistance | Light OFF | Light OFF |
| Dim indoor light | Medium resistance | Light ON | Light ON |
| Complete darkness | High resistance | Light ON | Light ON |

These findings confirm that the LDR sensor effectively regulates power usage based on environmental lighting, ensuring energy-efficient automation.

### g) Power Control Efficiency

The system's relay module was tested to evaluate its power-switching efficiency in response to object detection and light intensity variations. The results indicate that power control actions occurred with minimal delay (~200 ms response time).

Table 7: The relay module's response was observed under different conditions

| Object Detected? | Light Intensity | Expected Power Status | Actual Power Status | Response Time (ms) |
|---|---|---|---|---|
| Yes | Low light | ON | ON | 200 ms |
| No | Low light | OFF | OFF | 210 ms |
| Yes | Bright light | OFF | OFF | 190 ms |
| No | Bright light | OFF | OFF | 200 ms |

These results confirm that the system efficiently activates or deactivates devices based on real-time conditions, improving energy savings and automation.

The experimental results demonstrate that the proposed IoT-based object detection and power control system functions effectively in automating energy management. The key findings are:

I. **High Object Detection Accuracy:** The ultrasonic sensor detects objects with 100% accuracy up to 200 cm, making it suitable for various applications like smart lighting, security systems, and industrial automation.

II. **Effective Light-Based Power Control:** The LDR sensor correctly responds to ambient light conditions, ensuring that lights are turned ON only when necessary, thereby optimizing energy efficiency.

III. **Fast and Reliable Power Control:** The relay module operates within 200 ms, ensuring quick switching of electrical devices, which is essential for real-time applications.

IV. **Seamless IoT Integration:** The ESP32 microcontroller efficiently transmits data to the cloud, enabling remote monitoring and control, which enhances usability and convenience.

**Comparison with Existing Systems**

- Unlike traditional manual lighting systems, the proposed system automates power control based on real-time sensor data.
- Compared to camera-based object detection, this system is low-cost, power-efficient, and does not require complex image processing.
- Existing IoT-based solutions mainly focus on remote monitoring, whereas this system integrates both real-time automation and IoT connectivity.

## V. CONCLUSION

· The results confirm that the proposed system effectively reduces energy wastage, enhances automation, and provides real-time remote monitoring. It offers a cost-effective and scalable solution for smart homes, industries, and energy-efficient buildings. Future improvements may include expanding detection range, integrating additional sensors, and implementing AI-based decision-making for enhanced functionality.

## VI. FUTURE ENHANCEMENTS

While the proposed IoT-based object detection and power control system has demonstrated high efficiency in automation and remote monitoring, there is scope for further improvements.

The following enhancements can be considered to increase accuracy, scalability, and intelligence:

**a) Extended Object Detection Range**

- Upgrading the ultrasonic sensor or integrating infrared (IR) and LiDAR sensors can improve the detection range and precision, making it suitable for larger areas.
- Implementing multi-sensor fusion can enhance object detection accuracy by reducing false detections.

**b) Artificial Intelligence and Machine Learning Integration**

- Implementing AI-based decision-making can allow the system to learn from historical data and predict power usage patterns, optimizing energy consumption.
- Machine Learning models can improve object classification to differentiate between humans, pets, and other objects, enabling smarter control strategies.

**c) Enhanced IoT Connectivity and Cloud Integration**

- Expanding cloud connectivity with platforms like AWS IoT, Google Firebase, or Microsoft Azure can enhance data storage, analytics, and remote monitoring capabilities.
- Implementing 5G or LPWAN (LoRa, NB-IoT) can improve long-range communication and allow system deployment in remote areas.

**d) Mobile App Integration and Voice Control**

- Developing a dedicated mobile app for Android and iOS with an intuitive UI can allow users to monitor and control devices more effectively.
- Integrating voice assistants (Alexa, Google Assistant) can enable hands-free operation, making the system more user-friendly.

**e) Energy Harvesting for Sustainability**

- Implementing solar panels or energy harvesting modules can reduce dependency on external power sources, making the system eco-friendly and sustainable.
- Low-power design optimizations can extend battery life, making the system suitable for off-grid applications.

**f) Multi-Device and Smart Home Integration**

- Expanding the system to support multiple devices and appliances (fans, air conditioners, smart locks) can enhance its usability in smart home and industrial automation.
- Integrating with IoT protocols like Zigbee and Z-Wave can enable seamless interoperability with existing smart home ecosystems.

**g) Security and Data Privacy Improvements**

- Implementing end-to-end encryption and secure

MQTT/TLS protocols can enhance data security and prevent cyber threats.
    - Adding user authentication mechanisms can prevent unauthorized access to IoT-based remote control features.

By incorporating these enhancements, the proposed system can evolve into a more intelligent, scalable, and energy-efficient IoT solution,benefiting a wide range of applications including smart cities, industrial automation, and energy management systems.

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