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Automated Street Light System

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Abstract
Night travel has always been troublesome and considered hazardous due to persistent darkness. A mechanized road light system is smart and provides a secure night time environment for all street users, including pedestrians. The Road Light Automation system can reduce energy consumption and maintenance costs and also helps to decrease criminal activities to a certain extent. This system would provide remote access for streetlight maintenance and control. Currently, we maintain a manual system where the road lights are turned ON/OFF manually, leading to significant energy waste and high carbon dioxide emissions. This project primarily focuses on reducing energy wastage by increasing light intensity only during the movement of vehicles. The proposed street light system leverages IoT sensors to enhance energy efficiency and functionality. In this project, a Light Dependent Resistor is used to detect daylight and darkness, and Infrared sensors are used to sense the movement of vehicles on the road. The lighting source is LED, considering its photometric properties such as efficiency, longevity, cost, and power consumption. This system will help monitor and control the road light system, including defect recognition of the lights through the IoT module. The implementation of IoT sensors not only promotes sustainable energy practices but also establishes a responsive and intelligent structure for civic lighting.

Keywords
IR sensors, LDR sensors, Arduino Uno R3, Automated Street light, LED

I. INTRODUCTION

In recent years, the concept of smart cities has gained significant traction, aiming to improve urban living through the integration of technology and data-driven solutions. One prominent application within smart cities is IoT-based smart street lighting systems. These systems utilize Internet of Things (IoT) technology to enhance the efficiency, functionality, and sustainability of street lighting infrastructure. IoT-based smart street lights involve the deployment of connected devices and sensors to manage and control street lights more intelligently. Traditional street lighting systems typically operate on predefined schedules or light sensors, which may not be responsive to real-time conditions.

IoT-enabled systems use sensors, controllers, and communication technology to adapt street light operations based on various factors such as Environmental Conditions, Traffic and Pedestrian Activities and Energy Effieciency. Sensors can detect ambient light levels, adjusting street light brightness accordingly. For example, lights can dim during moonlit nights or brighten during overcast weather. Motion sensors and cameras can detect the presence of vehicles, cyclists, or pedestrians, brightening lights in real-time to improve safety and visibility. IoT systems optimize energy consumption by dimming or turning off lights when they are not needed, reducing operational costs and environmental impact.

IoT devices communicate over wireless networks (e.g., cellular, Wi-Fi, LoRaWAN) to transmit data to a central management system. Centralized management system processes data received from sensors, making decisions on light intensity and scheduling based on predefined algorithms or real-time conditions. Controllers adjust individual or groups of street lights based on commands received from the management system. Benefits of IoT based street light such as, Significant reduction in energy consumption by dynamically adjusting lighting levels, Lower operational costs due to reduced energy usage and maintenance efforts, Improved visibility and security through adaptive lighting in response to environmental conditions and activity, Decreased light pollution and carbon footprint by using energy more efficiently.

The Challenges that are faced in this system are cost , security and interoperability. IoT-based smart street lighting represents a critical component of the broader smart city initiative. As technology advances and costs decrease, more cities are expected to adopt these systems to enhance urban sustainability, efficiency, and citizen well-being. Continuous innovation in IoT, sensors, and data analytics will further refine these systems, making them more responsive and adaptive to urban environments.

Since 16th century street lights have undergone many changes and updates to become what it is today. These traditional lights also have their pros and cons. Hence sometimes mistakes happen. Like light remains ON even during the day. And by mistake sometimes lights remain OFF even during the nights. Street lights also run using the electricity supplied by the respective electric boards. And so when in the night, the supply is cut off due to any reason, the surrounding is completely engulfed in darkness as street lights and also the lights from our homes go OFF. This also leads to confusion and accidents.

LDRs (Light Dependent Resistors) are the trigger to turn ON and OFF the smart street lights at Twilight.LEDs are used in place of Sodium lights which are both energy and cost efficient. Overall this system is costly to install but is profitable in the long run. IoT-enabled street lights are equipped with a variety of sensors that collect real-time data on environmental conditions such as ambient light levels, temperature, humidity, and even air quality. These sensors enable adaptive lighting solutions that respond intelligently to changing conditions.

Utilizing wireless communication technologies such as Wi-Fi, cellular networks, or Low-Power Wide-Area Networks (LPWANs) like LoRaWAN, smart street lights can transmit data to centralized management systems. This connectivity allows for remote monitoring, control, and optimization of street lighting operations. Centralized management systems receive and analyze data from sensors to make informed decisions regarding lighting intensity, scheduling, and maintenance needs.

II. LITERATURE SURVEY

Kumar et al. [2] presents a Smart Street Lighting System leveraging IoT technology to optimize energy consumption by activating lights only when necessary. The system employs an STM32 microcontroller, ESP32 Wi-Fi module, LED lights, IR detector, LDR detector, L298N motor drivers, and ThingSpeak cloud. The LDR detector assesses darkness levels to activate the lights, while the IR detector adjusts brightness based on object detection. Data generated by the system is visualized on ThingSpeak, offering insights into power consumption and energy optimization. The study demonstrates significant energy savings and effective energy management through the IoT-enabled system.

Shah [1] explores an IoT-based Smart Street Lighting System aimed at reducing energy consumption by activating lights only when needed. Utilizing an STM32 microcontroller, ESP32 Wi-Fi module, LED lights, IR detector, LDR detector, L298N motor drivers, and Thing Speak cloud, the system operates similarly to the one described in Paper 1. The LDR detector triggers the lights based on darkness levels, while the IR detector adjusts brightness accordingly. Data collected by the system is analyzed on ThingSpeak, providing insights into power usage and energy optimization.

Thipards et al. [3] discusses a smart road lighting control system designed to save electricity via the Internet of Things (IoT). The system features LED luminaires controlled by Passive Infrared Sensor (PIR) regulators, allowing efficient operation based on motion detection. Additionally, smart lighting poles are equipped with PM2.5 detectors, IP cameras, and a Wi-Fi system, all managed by a microcontroller. The implementation results in 64% energy savings and enhanced life safety through surveillance provided by the IP cameras. The IoT system shows potential for diverse applications, such as energy savings in smart homes, farms, offices, and electricity management, utilizing deep learning and machine learning approaches. These studies collectively highlight the significant benefits of IoT-enabled smart street lighting systems in terms of energy savings and operational efficiency. They underscore the role of various sensors and cloud-based data analysis in optimizing lighting systems to meet real-time demands.

III. EXISTING SYSTEM

The evolution of smart street lighting systems can be divided into several generations, each representing advancements in technology, functionality, and integration of smart capabilities. Here's an overview of the history and generations of smart street light systems:

First Generation: Traditional Street Lighting

Description: Traditional street lighting systems typically consisted of basic lighting fixtures controlled by timers or photocells. These systems operated on fixed schedules, turning on and off at predetermined times regardless of environmental conditions or actual lighting needs.

Features: Simple lighting control based on time or light sensors. Limited capability for energy efficiency and adaptive lighting.

Second Generation: Remote Monitoring and Control

Description: The second generation saw the introduction of remote monitoring and control capabilities through centralized management systems. This enabled municipalities to monitor the operational status of street lights and adjust lighting schedules remotely.

Features: Integration of communication technologies (e.g., wireless networks) for data transmission between street lights and centralized management platforms. Improved energy management and maintenance efficiency compared to traditional systems.

The drawbacks of the above mentioned systems are:

Fixed Schedules

Issue: Traditional street lighting systems operate on fixed schedules based on timers or light sensors, regardless of actual lighting needs. This can result in lights being on when not required, leading to unnecessary energy consumption during daylight hours or periods of low activity.

Impact: Increased energy costs and environmental impact due to inefficient use of electricity.

Limited Control and Adaptability

Issue: Lack of real-time control and adaptability to changing environmental conditions such as weather changes or unexpected events (e.g., accidents, gatherings).

Impact: Reduced visibility and safety during critical periods, potential for increased crime rates in poorly lit areas.

Maintenance Challenges

Issue: Reactive maintenance approach where problems are only addressed after they occur, leading to higher maintenance costs and longer response times.

Impact: Higher risk of light outages or malfunctions impacting public safety and citizen satisfaction.

IV. PROPOSED SYSTEM

While traditional and remote street light monitoring systems have served their purpose, they exhibit limitations in terms of energy efficiency, adaptability, and maintenance efficiency. Each of the conventional approaches do possess a drawback or a flaw which pulls down the efficiency of the system to a great extent. Thus, we incorporate modifications to the conventional lightning system and are proposing the same in this report.

IoT-based smart street lighting systems address these drawbacks by offering real-time monitoring, adaptive control, energy optimization, and predictive maintenance capabilities. As technology continues to advance, the transition towards smarter and more interconnected urban lighting infrastructure is expected to accelerate, providing cities with opportunities to enhance sustainability, safety, and overall quality of life for residents and visitors.

The proposed system has several features that helps to overcome the drawbacks of the existing lightning systems.

- Motion Sensing: Detects movement to activate lights, improving energy efficiency.
- Light Intensity Adjustment: Automatically adjusts brightness based on ambient light levels or specific requirements.
- Remote Monitoring: Allows real-time monitoring and control of street lights through a centralized platform.
- Energy Consumption Tracking: Monitors energy usage, enabling better resource management and cost optimization.

- Smart Scheduling Enables preset schedules for turning lights on/off or adjusting brightness at specific times.
- Fault Detection and Reporting: Identifies and reports malfunctions, facilitating quick maintenance.
- Environmental Sensors: Integrates sensors for monitoring air quality, temperature, or other environmental factors.
- Wireless Connectivity: Utilizes wireless communication for seamless connectivity and data exchange.
- Emergency Response Integration: Can be programmed to respond to emergencies by altering lighting patterns or intensity.

V. System Design And Implementation

The block diagram shown in Figure 1 illustrates the Automatic street lights using different sensors, proposed as a part of this project.

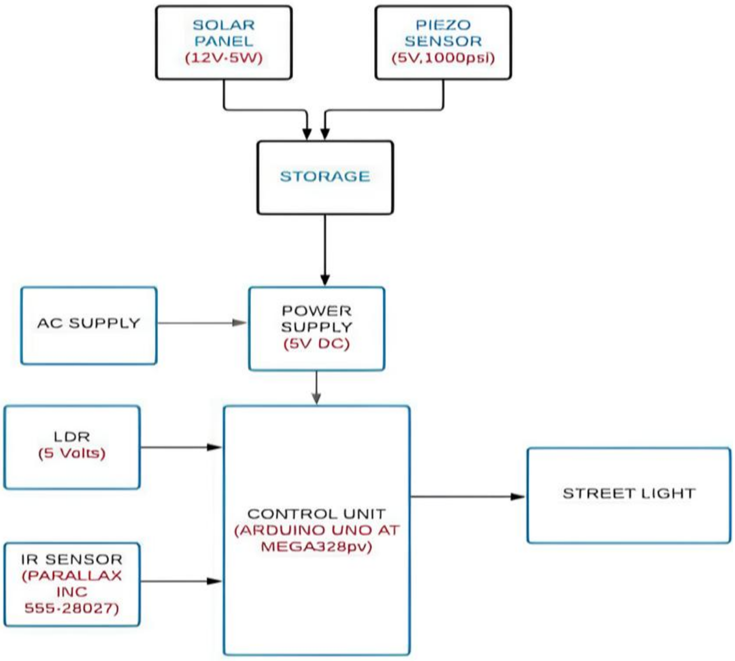

Figure 1

Three primary sensors in the diagram sense various elements in our environment. LDRs, current sensors, and infrared sensors are these. Data is gathered from various sensors that are fixed to every pole and sent to the control unit, which is precoded to meet our needs. The output signal is then transmitted to the Arduino UNO minicomputer, which stores the data. From there, a feedback signal is produced and sent back to the control unit, which in turn sends it to the street light poles. turning on, off, or dimming the lights in accordance with the feedback received. With the aid of the internet, the information kept in the small computer can also be utilized to send notifications on a website or app based on the needs.

VI. WORKING MODULES

- Arduino Uno
- Light Dependent Resistor (LDR)
- Light Emitting Diode (LED)
- IR Sensor

The above-mentioned modules highlight the major algorithms which have been considered for analysis and implementation.

VII. DESCRIPTION OF EACH MODULE

This section elucidates the different working modules and components involved in the development of the project so as to carry out necessary comparisons and analyses.

Arduino Uno

Arduino Uno is an open-source microcontroller board based on the ATmega 328p microcontroller which is developed by the Arduino Company. This board consists of digital and analog input/output pins which are further connected to other devices, electronic component, and circuits.

This board consists of 14 input and output pins, out of which 6 analog input/output pins and 6 are capable of PWM outputs and these are programmable with Arduino IDE (Integrated Development Environment) with B-type USB cable. It accepts voltage between 7 and 20 volt and this can be powered by USB cable or external 9-volt battery. It consists of everything that is needed to support the microcontroller and it can be operated by simply connecting to a computer with a USB or a power source with AC or DC adaptor.

Light-Dependent Resistor (LDR)

The light-dependent resistor is an electronic component that is used to detect light and used in the operation of the circuit depending upon the intensity of light. It is used in an electrical circuit where there it is important to detect the presence of light and to measure the intensity of light. There are various names used for this light-dependent resistor is the light-dependent resistor (LDRs), photo resistor, even photoconductor, or photocell.

The same function of LDR is also performed by electronic components like photodiode or phototransistor. a little amount of light level changes the large resistance of the circuit so it is preferred or is being convenient to choose in many electronic circuits design.

LED

LED lighting benefits both end users and professionals in a number of ways:

- High Intensity and Brightness: LEDs have a high lumen output, excellent color quality, and high light intensity.
- Energy Efficiency: Compared to incandescent and halogen lights, LEDs have a higher energy efficiency.
- Low Voltage and Current Requirements: LEDs are flexible and simple to use because of their low voltage and current requirements, which make installation simple.

- Minimal Heat Emission: LEDs produce very little heat, which makes them ideal for small spaces and areas that are sensitive to heat.
- High Reliability: Because LEDs don't have any moving parts, they can withstand a variety of environmental factors, such as cold temperatures and environments that vibrate a lot.

IR Sensor

An infrared sensor is a type of sensor that senses its environment, such as motion or an object's temperature. Since all objects emit some kind of thermal radiation, these sensors are limited to measuring the infrared spectrum. IR sensors can detect this type of radiation, but human eyes cannot.

An IR LED serves as the emitter, and an IR photodiode, which is sensitive to IR light with the same wavelength as the LED, serves as the detector. As soon as the photodiode is exposed to infrared light, resistances and output voltage alter.

Infrared technology is incredibly useful in daily life. For example, TVs can comprehend signals better thanks to IR sensors. IR sensors are useful because of their convenient features, straightforward design, and low power consumption. The infrared spectrum cannot be seen by the human eye.

Infrared radiations are present in the visible and microwave portions of the electromagnetic spectrum. These waves typically have wavelengths between 0.7 and 1000 µm. Three general regions can be identified in the infrared spectrum: near-, mid-, and far-infrared. The wavelength ranges for the near-infrared region are 0.75 to 3 µm, the mid-infrared region is 3 to 6 µm, and the far-infrared region is greater than 6 µm.

Classification of Infrared Sensors

Active Sensors

- Contain both a transmitter (usually LED or laser diode) and a receiver.
- Work by detecting energy radiation to gather information.
- Examples: Reflectance sensor, break beam sensor.

Passive Sensors

- Contain only a detector, relying on external IR sources.
- Detect emitted energy through an IR receiver.
- Examples: Pyro electric detector, bolometer, thermocouple-thermopile

Figure 1 Arduino UNO R3

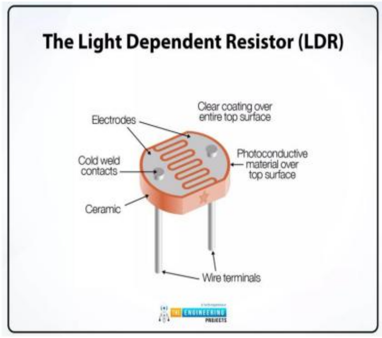

Figure 2 LDR

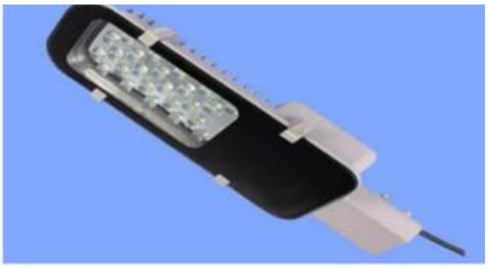

Figure 3 LED

Figure 4 IR Sensor

VIII. Results and Discussion

Major improvements have been observed in a number of important metrics since the automated streetlight system with IR sensors, LDR, and Arduino Uno R3 was implemented. Above all, the system has shown impressive increases in power efficiency. The system uses LDR to track ambient light levels and IR sensors to identify the presence of cars and pedestrians. This allows the system to dynamically modify the operation of LEDs, which represent street lights, based on current environmental conditions. By ensuring that street lights are only turned on or turned down when needed, this adaptive control technique helps to reduce the amount of energy that is wasted when there is sufficient ambient light or little activity.

Furthermore, by decreasing the manual errors connected with conventional, manually operated street lighting systems, the system has demonstrated improved operational reliability. With automated control based on sensor inputs, environmental conditions can be changed quickly, and optimal lighting levels can be maintained throughout the day and in a variety of weather situations. In addition to enhancing street safety and visibility, this dependability raises the overall effectiveness of managing urban infrastructure.

Effective control of street lights is made possible by the incorporation of algorithms into the Arduino code, which guarantees adaptive brightness adjustments in response to sensor inputs. In order to further optimize system management, future improvements may include a user-friendly interface for visualizing real-time data and manual override capabilities.

IX. Conclusion

This study concludes by showing the advantages and real-world applications of sensor-based automation in street lighting systems. The project has effectively increased power efficiency, reduced operational errors, and improved responsiveness to real-time environmental conditions by integrating IR sensors, LDR, and Arduino Uno R3. These accomplishments demonstrate why automated street lighting systems, by reducing the energy consumption and improving operational reliability, can contribute meaningfully to sustainable urban development.

Subsequent research and development endeavors ought to concentrate on optimizing algorithms, enhancing user interfaces, and broader system scalability to encapsulate more expansive urban regions.

X. FUTURE ENHANCEMENTS

Advanced Algorithms: Apply predictive analytics and machine learning to forecast lighting requirements based on historical data, improving responsiveness and energy efficiency.

IoT Integration: To enable data analytics and system scalability, leverage IoT for cloud connectivity, remote control, and real-time monitoring.

Advanced Sensor Technology: Modernize the sensors with advanced sensor technology to detect changes in the surroundings more accurately, allowing for accurate and adaptive lighting adjustments.

Integration with Smart City Infrastructure: To maximize energy efficiency and improve urban functioning, work with traffic management and smart grid systems.

Scalability and adaptability: To handle urban growth and emerging technologies, design systems with modular components and highly customizable strategies.

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