IoT based Smart Street Light

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Abstract

This paper presents a street light automation based on IoT that works on smart sensing sensors and processing device. Street light is important for public safety and luminance, but it can also be a wastage of lots of energy if they are not turned off when they are not needed. By using IoT based Automation, we can control the intensity of street light which can save energy at low cost. Further we can control and switch on, off or change its intensity of the street light, thus by using semi-conductor devices we can easily control the output for better efficiency. By using internet of things-based automation we can get desired outputs by increasing the life and efficiency of the system and will result in quality life change as its major purpose is public safety by making the visibility of light.

Keywords: Arduino Uno, IR Sensor, LDR, LED, Resistor, Smart Automation

1. Introduction

City illumination involves significant expenses, encompassing both energy consumption and maintenance costs that account for about 40% of related budgets. By transitioning to intelligent street lighting systems, municipalities can achieve considerable savings while simultaneously transforming into smarter urban environments and fostering interactive engagements with residents, local enterprises, and tourists. The current approach, which relies on manual switching, results in wasteful electricity usage due to premature activation of streetlights before complete darkness sets in.

To address this issue, the proposed project introduces an innovative Internet-of-Things (IoT) system designed specifically for energy conservation among streetlight installations. It replaces traditional methods by incorporating Infrared (IR) sensors and Light Intensity sensors alongside an Arduino Uno microcontroller platform. These components enable automatic detection of traffic flow via IR sensors and monitoring of ambient light levels using Light Intensity sensors. Consequently, the system controls the activation and adjustment of streetlight brightness according to real-time conditions, thereby minimizing unnecessary energy expenditure [3].

2. History of Street Light

The history of street lighting dates back to ancient times when oil lamps were used to light the streets. The first recorded use of street lighting in the United States was in Philadelphia in 1757, where Benjamin Franklin introduced colonial-era streetlights that were lit by candles placed inside a glass vessel. The first electric streetlights were introduced in the United States in Wabash, Indiana, in 1880, using the "Brush Light" invented by Charles F. Brush of Cleveland, Ohio. By the beginning of the 20th century, streetlights had become widespread, and they have continued to evolve with the development of more efficient lighting technologies such as mercury lights and LEDs.

There are various types of street lights, including high-pressure sodium (HPS), metal halide, LED (light-emitting diode), Solar-Powered Street Lights and Fluorescent lights. LED street lights have become increasingly popular due to their energy efficiency and longer lifespan. Modern street lights often include sensors and controls for smart lighting systems that can adjust brightness based on ambient conditions or user-defined schedules.

3. Understanding Smart Streetlights: A Comprehensive Overview

Advanced smart street lighting represents a modern approach to public lighting in urban and suburban areas, integrating innovative technologies to enhance efficiency, functionality, and sustainability. Traditionally, street lighting relied on high-pressure sodium lamps, but advanced solutions utilize cutting-edge technologies to offer numerous benefits.

Key components of advanced smart street lighting include:

- **LED Technology:** LED lights serve as the standard due to their energy efficiency, long lifespan, and superior brightness and colour rendering compared to older lighting technologies.
- **Energy Efficiency:** LED street lights consume significantly less energy than traditional options, leading to reduced energy bills and greenhouse gas emissions, making them both environmentally friendly and cost-effective.
- **Smart Control Systems:** These systems enable remote monitoring and management of individual street lights or entire networks, adjusting brightness levels based on real-time data such as traffic density, weather conditions, or daylight levels to improve energy efficiency.
- **Dimming and Adaptive Lighting:** Dimming capabilities allow adjustments during off-peak hours or in low-traffic areas, while adaptive lighting responds to pedestrian or vehicle presence, ensuring safety and minimizing energy wastage.
- **Sensors and IoT Integration:** Sensors integrated into these systems optimize energy usage and enhance security, triggering lighting changes based on specific conditions or events.
- **Maintenance Alerts:** Smart systems detect faulty lights and send alerts for timely maintenance, improving overall reliability.
- **Data Collection and Analysis:** Advanced Street lighting serves as a data collection platform for smart city initiatives, supporting traffic management, environmental monitoring, and urban planning.
- **Environmental Benefits:** LED lighting reduces energy consumption and light pollution, contributing to better stargazing conditions and improved night-time visibility.
- **Cost Savings:** While initial installation costs may be higher, long-term savings from energy efficiency and reduced maintenance outweigh the upfront investment.
- **Safety and Security:** Enhanced visibility and adaptive lighting improve safety for pedestrians and drivers, creating safer streets at night.

4. Manufacturing of Street Light

Advanced smart street lighting plays a pivotal role in smart city development, enhancing urban life quality through interconnected infrastructure and data-driven decision-making, while also promoting sustainability, cost savings, and a safer environment. The process step by step mentioned below.

4.1 LDR

As shown in Figure.1, an LDR or light dependent resistor which is also known as photo resistor, photocell, photoconductor, is a type of resistor that changes its resistance based on the intensity of light exposed to surrounding environments. It is also referred to as a photocell or photoconductive cell. The Light Dependent Resistor (LDR) is employed to sense the ambient light levels and control the activation of the street lights. When integrated with the Arduino Uno, the LDR enables the system to automatically turn on the street lights when the ambient light levels decrease, such as at dusk or in low light conditions. This technology offers advantages such as energy savings and enhanced safety by providing adaptive and responsive illumination based on the ambient light levels. The practical application of LDR sensors in smart street lighting projects demonstrates their role in creating energy-efficient and intelligent lighting systems for urban environments [9].

4.2 Arduino Uno

The Figure.2 illustrates that the Arduino Uno is a microcontroller board that is open-source and based on the Microchip ATmega328P microcontroller. It was created by Arduino.cc and was first released in 2010. The board has digital and analog input/output pins that can be programmed using the Arduino

IDE through a USB cable. It can be powered by either a USB cable or an external power source with a voltage range of 7-20V. The board has 14 digital I/O pins, 6 analog I/O pins, and uses the ATmega16U2 (or Atmega8U2 up to version R2) as a USB-to-serial converter. The name "uno" means "one" in Italian, indicating a significant redesign of the Arduino hardware and software. The board is distributed under a Creative Commons Attribution Share-Alike 2.5 license, and its hardware reference design is available on the Arduino website.

Figure1: LDR (Light dependent resistor)

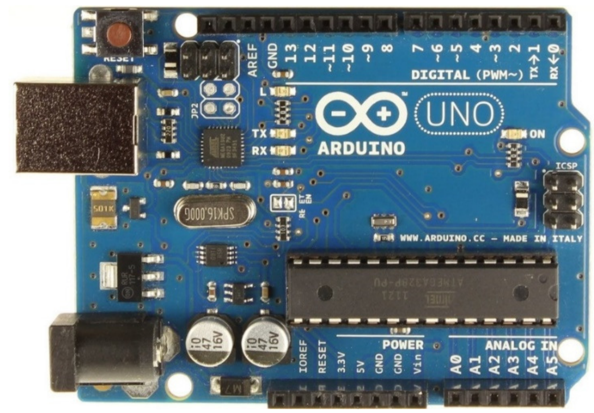

Figure2: Arduino Uno R3

The Arduino Uno has been utilized in various projects, including smart street lighting systems. In these systems, the Arduino Uno R3 serves as the central control unit that manages the inputs from the IR and LDR sensors and controls the activation of the street lights. The Arduino Uno R3 is connected to the LDR and IR sensors, and based on the input received from these sensors, it triggers the activation and deactivation of the street lights. The integration of the Arduino Uno R3 with the sensors enables the system to create an adaptive and responsive street lighting system, thereby enhancing energy efficiency and safety. The Arduino Uno R3 acts as the brain of the smart street light system, processing the sensor inputs and controlling the illumination of the street lights based on the detected environmental conditions and vehicle presence [16].

4.3 IR Sensor

As shown in Figure.3, IR sensors when combined with Arduino Uno, detect vehicle presence and

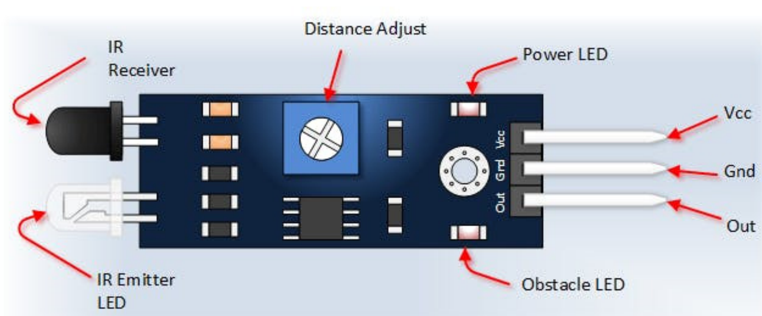

Figure3: Infrared Sensor

control street light illumination. Multiple IR sensors sense vehicle position and activate corresponding LEDs, offering energy savings and improved safety. IR sensors emit and detect infrared light, enabling the creation of adaptive lighting systems that respond to vehicle presence, enhancing energy efficiency and safety. The practical application of IR sensors in smart street lighting projects demonstrates their role in creating energy-efficient and responsive lighting systems for urban environments [8], [10]-[12].

4.4 Resistor

As shown in Figure.4, resistors are used to decrease voltage and current flow in specific areas of the circuit. The 10k resistor is used in the smart street light project in conjunction with the Light Dependent Resistor (LDR) and the Arduino Uno. It is part of the voltage divider circuit with the LDR, allowing the system to sense the ambient light levels [4]. The 10k resistor helps in adjusting the voltage levels in the circuit, enabling the LDR to effectively detect changes in light intensity. This setup allows the system to automatically control the activation and deactivation of the street lights based on the ambient light conditions, thereby contributing to energy savings and improved safety [2], [3].

Figure 4: 10k Ohm Resistor

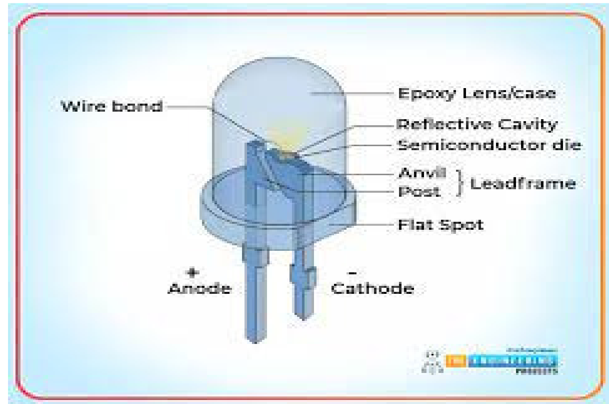

Figure 5: LED (Light Emitting Diode)

4.5 LED

As shown in Figure.5, Light Emitting Diodes (LEDs) are used as the output for the entire circuit. LEDs are employed to illuminate the street lights based on the inputs received from the IR and LDR sensors. They offer advantages such as energy efficiency, long lifespan, and low maintenance costs, making them an ideal choice for road lighting applications. The use of LEDs in smart street lighting projects contributes to energy savings and improved safety, as they can be controlled to provide targeted illumination based on the presence of vehicles or ambient light levels. The practical application of LEDs in smart street lighting systems demonstrates their role in creating energy-efficient and responsive lighting solutions for urban environments [2].

5. Architecture

This project's core is its luminance controlling, Figure.6 showing architecture. Its purpose is to controlling ON/OFF lights automatically or we can control brightness of the lights by using sensors and IoT based system. This whole controlling block diagram is shown in Figure.7.

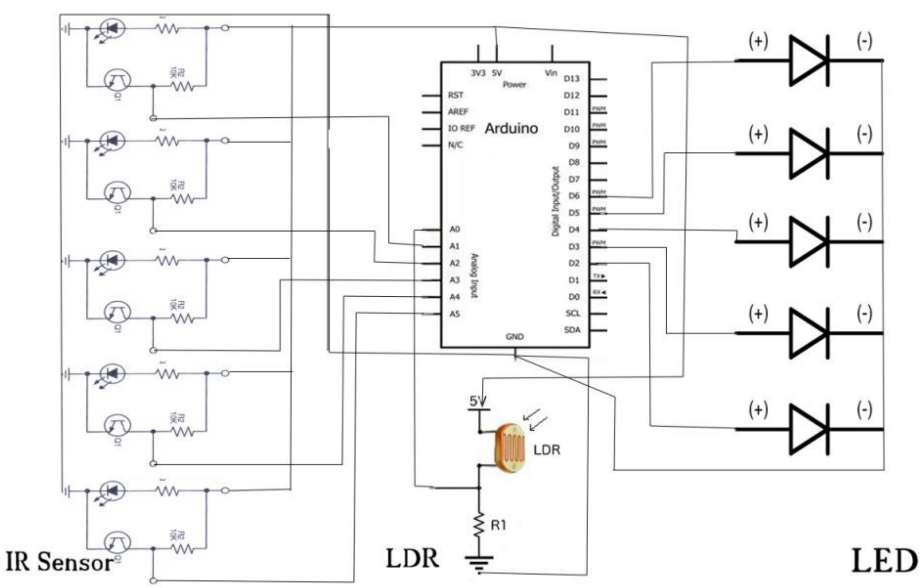

Figure 6: Architecture of Circuit

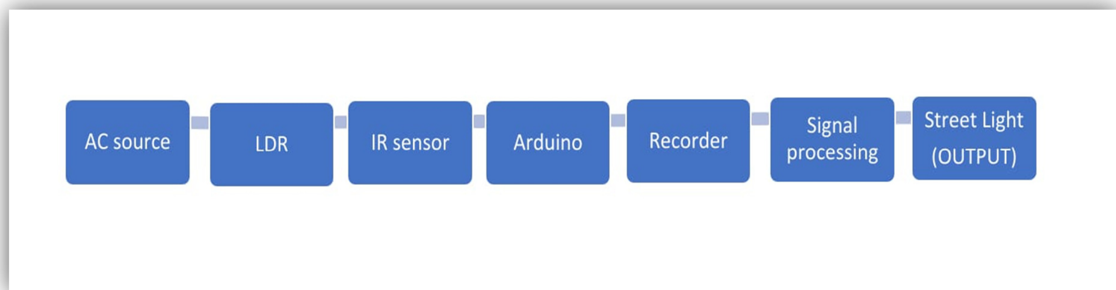

Figure 7: Block diagram of working process

5.1 Street Light Assembling

Street light assembly involves a series of systematic steps to ensure proper installation and functionality [13]-[15]. Below is a general outline of the assembly process:

1. Prepare components and tools.
2. Set up the foundation.
3. Attach the lamp holder to the fixture.
4. Install the fixture onto the pole.
5. Connect electrical components and wiring.
6. Verify wiring and fixture functionality.
7. Secure the pole to the foundation and raise it.
8. Fine-tune the fixture's position.
9. Perform safety checks and inspections.
10. Power up the street light and conduct testing.
11. Clean the installation area and document the process.

Establish a maintenance plan for ongoing upkeep. It's essential to follow manufacturer's instructions and regional requirements for accurate assembly. Always prioritize safety and consult relevant documentation for proper street light installation [18].

6. Methodology

First of all, we are discussing Activation/Deactivation Process of Street lights; The switching procedure for street lights involves turning them on and off based on a predetermined schedule or environmental conditions [5]-[7]. Here's a general overview:

➢ **Turning Street Lights On (Activation):**

- Scheduled Activation: Street lights are programmed to automatically turn on at specific times, typically at dusk or when ambient light levels decrease.
- Light Sensors: Light-sensitive sensors trigger street lights to turn on when ambient light levels drop to a certain threshold.
- Motion Sensors: Motion sensors activate street lights when movement is detected, conserving energy during low-traffic periods.
- Remote Control: Municipal authorities or maintenance teams can remotely activate specific lights or zones as needed.
- IoT-Based Control: Smart Street lighting systems use IoT connectivity to optimize when and how lights are turned on, considering factors like traffic flow and weather conditions.

Now when the Street Light is ON then also essentially, there are two scenarios:

1. When an object is detected in close proximity to the IR sensor;

✓ IR sensor detects the presence of an object within its range.
✓ Voltage output of the IR sensor increases.
✓ Arduino or microcontroller receives the signal from the IR sensor.
✓ Microcontroller triggers an action, such as turning on a light or activating an alarm.
✓ Timestamp data is logged indicating the time of object detection.
✓ Distance measurement data from the IR sensor is recorded.

2. When there is no object within the detection range of the IR sensor;

- ✓ IR sensor does not detect any object within its range.
- ✓ Voltage output of the IR sensor remains at a baseline level.
- ✓ Arduino or microcontroller does not receive any signal from the IR sensor indicating object absence.
- ✓ No action is triggered by the microcontroller.
- ✓ Timestamp data is logged indicating the time of no object detection.
- ✓ Distance measurement data from the IR sensor remains constant at the maximum range value.

➢ Turning Street Lights Off (Di-activation):

- Scheduled Deactivation: Street lights are programmed to turn off at specific times in the morning or when daylight levels rise.
- Light Sensors: Street lights equipped with light sensors turn off when sufficient daylight is detected.
- Motion Sensors: Street lights may turn off when motion is no longer detected to conserve energy.
- Remote Control: Authorities may remotely deactivate lights, especially during daylight hours or emergencies.
- IoT-Based Control: Smart systems dynamically adjust lighting levels or turn off lights based on real-time data.
- Override Switches: Manual switches may allow authorized personnel to control lights manually.

Advancements in smart city technology have led to more adaptive and energy-efficient methods for controlling street lighting, reducing energy consumption, light pollution, and enhancing safety and visibility.

6.1 Protocol for Luminance Management

The process for controlling luminance in smart street lights utilizing Arduino and IoT-based technologies entails a thorough system setup and control strategy. Initially, hardware components such as Arduino microcontrollers, light sensors, communication modules, and LED fixtures are assembled and integrated. Firmware development enables Arduino controllers to gather data from light sensors and communicate with the IoT platform via protocols like MQTT or HTTP. Strategically positioned light sensors monitor ambient light levels continuously throughout the street lighting network. Data from these sensors is transmitted to the IoT platform for storage and analysis. Algorithms are then implemented to process this data, considering factors like ambient light, traffic density, time of day, and weather conditions. Based on this analysis, Arduino controllers adjust LED fixture brightness using pulse-width modulation (PWM), resulting in adaptive lighting control. Dynamic scheduling algorithms optimize lighting levels, while user-friendly interfaces allow city officials to monitor and manually intervene if necessary. Energy efficiency measures, including dimming during off-peak hours and motion sensor activation, are incorporated to reduce energy consumption. Continuous monitoring, remote maintenance, security measures, and scalability considerations complete the procedure, ensuring efficient and responsive luminance control for smart street lights, meeting energy conservation goals, and enhancing overall safety and sustainability [14], [17].

7. Result and Discussion

After extensive efforts, the smart street light automation project has achieved significant milestones. Through stakeholder engagement and brainstorming sessions, the project has identified key priorities and challenges. The implementation phase is now underway, focusing on energy efficiency enhancements, robust remote monitoring systems, and the integration of advanced data analytics for predictive maintenance. The project also incorporates measures to address user accessibility, data privacy concerns, and scalability challenges. With ongoing community engagement and strategic partnerships, the project is poised to deliver tangible benefits, including cost reduction, enhanced safety, and environmental sustainability. Figure.8 the final product shows:

- ✓ Automatic switching of street lights based on the presence of vehicles or ambient light intensity.
- ✓ Maintenance cost reduction through predictive maintenance and remote monitoring systems.
- ✓ Energy conservation and cost savings by adjusting light intensity based on real-time data and traffic conditions.

- ✓ Integration with IoT networks for centralized control, energy monitoring, and emission reduction.
- ✓ Enhanced safety and security through on-demand lighting and adaptive brightness adjustments.
- ✓ Visual management and remote control of street lights based on traffic flow, time, and weather conditions.
- ✓ Built-in sensors and smart plugs for accurate control of switch state and lighting brightness, enabling on-demand lighting and energy savings.
- ✓ Alarm systems for proactive maintenance and abnormal conditions, contributing to intelligent public lighting management.

Figure8: Final end Product

8. Conclusion

The development of an IoT-based smart street light automation project is a complex undertaking with numerous challenges, but it holds great promise for enhancing urban living. The project has identified key priorities and challenges through stakeholder engagement. The project aims to improve energy efficiency, enhance safety and security, enable data-driven decision-making, engage with the community, and promote sustainability. The project incorporates energy-efficient LED lighting, motion sensors, and ambient light sensors to significantly reduce energy consumption, leading to cost savings and environmental benefits. The inclusion of surveillance cameras and emergency lighting features improves public safety and can assist law enforcement agencies in monitoring public spaces. The project generates valuable data on traffic patterns, environmental conditions, and street light performance, which can be used to inform urban planning and optimize city operations. The project aligns with sustainability goals by reducing energy consumption and carbon emissions, contributing to a greener urban environment.

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