LIGHTWAVE

Design & developed by

A. V. N. S. S. Vaidehi 2211CS050153
K. Koushik Goud 2211CS050172

GUIDED BY

Dr. G. Anand Kumar
(Head of the Department)

Department of Computer Science & Engineering
(INTERNET OF THINGS)
IIIYR-IISEM
Malla Reddy University, Hyderabad

2022-2026

MALLA REDDY UNIVERSITY

(Telangana State Private Universities Act No.13 of 2020 and G.O.Ms.No.14, Higher Education (UE) Department)

CERTIFICATE

This is to certify that this is the bonafide record of the application development entitled **"LIGHTWAVE ",** submitted by **A. V. N. S. S. Vaidehi (2211CS050153)**, **K. Koushik Goud(2211CS050172)** B.Tech III year II semester, Department of CSE (IoT) during the year2024 – 2025. The results embodied in this report have not been submitted to any other University or institute for the award of any degree or diploma.

Internal Guide
Dr. G. Anand Kumar
(Head of the Department)

Head of the Department
Dr. G. Anand Kumar
CSE(IoT)

External Examiner

ACKNOWLEDGEMENT

I extend our sincere gratitude to all those who have contributed to the completion of this project report. Firstly, we would like to extend our gratitude to Dr. V. S. K Reddy, Vice-Chancellor, for his visionary leadership and unwavering commitment to academic excellence. I would also like to express our deepest appreciation to our project guide Dr. G. Anand Kumar , Associate Professor, Dept. of Cyber Security & IoT, whose invaluable guidance, insightful feedback, and unwavering support have been instrumental throughout this project for successful outcomes. I am also grateful to Dr. G. Anand Kumar, Head of the Department of Cyber Security & IoT, for providing me with the necessary resources and facilities to carry out this project. I extend our gratitude to our PRC convenor, Dr. G. Latha, for giving valuable inputs and timely guidelines to improve the quality of our project through a critical review process. I thank our project coordinator, Dr. G. Latha, for his timely support. I would like to thank Dr. Kasa Ravindra, Dean, School of Engineering, for his encouragement and support throughout my academic pursuit. I heartfelt thanks also go to Dr. Harikrishna Kamatham, Associate Dean School of Engineering for his guidance and encouragement. I am deeply indebted to all of them for their support, encouragement, and guidance, without which this project would not have been possible.

A. V. N. S. S. Vaidehi 2211CS050153

K. Koushik Goud 2211CS050172

ABSTRACT

LightWave is a smart IoT-based lighting system designed to revolutionize the way street lighting is managed and utilized. This system employs advanced sensors to dynamically adjust light intensity based on real-time factors such as human presence, ambient light levels, weather conditions, and air quality. For instance, during peak traffic hours or when pedestrians are detected, the system increases brightness for enhanced safety, while dimming or turning off lights during low-traffic periods to conserve energy. A rain sensor adjusts light intensity during adverse weather, ensuring visibility without unnecessary energy waste. Meanwhile, the air quality monitoring feature continuously evaluates environmental conditions and triggers alerts during poor air quality scenarios, fostering public health awareness. The inclusion of an emergency mode allows for high-intensity lighting during critical situations such as accidents or natural disasters, making the streets safer for everyone.

Beyond its immediate functionality, LightWave incorporates data logging to record sensor readings for long-term analysis and system optimization. This data can aid city planners and municipal authorities in evaluating energy usage patterns and improving resource management strategies. The system’s seamless automation enhances convenience while reducing human intervention, promoting operational efficiency. By combining smart automation, sustainability, and environmental awareness, LightWave addresses modern urban challenges while reducing carbon footprints.

Table of Contents

1. INTRODUCTION

1.1 Problem Definition & Description

Traditional street lighting systems operate inefficiently, consuming energy even when there is no activity in the area. They lack the ability to adapt to environmental factors such as weather conditions or air quality. This results in excessive energy waste, high operational costs, and a negative environmental impact. Moreover, these systems fail to provide enhanced safety features during emergencies like accidents or natural disasters. Addressing these limitations is critical to modernizing urban infrastructure for sustainability and efficiency.

The "LightWave" project aims to develop a smart IoT-based lighting system that dynamically adjusts light intensity based on motion detection, ambient light levels, weather conditions, and air quality. The system uses advanced sensors to ensure energy conservation while maintaining visibility and safety. It also includes an emergency mode for critical situations and logs data for further analysis and optimization. By integrating automation with sustainability, LightWave addresses the inefficiencies of traditional systems and aligns with global smart city initiatives. This innovative approach ensures reduced costs, lower carbon emissions, and enhanced public safety.

1.2 Aim & Objectives of the Project

To develop an IoT-based smart lighting system, LightWave, that optimizes energy efficiency, enhances safety, and promotes environmental sustainability by dynamically adjusting light intensity based on real-time data such as motion detection, ambient light levels, weather conditions, and air quality.

- **Energy Conservation**: Reduce energy consumption by adjusting light intensity dynamically based on motion and ambient light conditions.
- **Weather Adaptability**: Ensure optimal lighting during adverse weather conditions such as rain or fog.
- **Environmental Monitoring**: Integrate air quality sensors to monitor pollution levels and provide alerts in case of poor air quality.
- **Enhanced Safety**: Incorporate an emergency mode to activate high-intensity lighting during critical situations like accidents or natural disasters.

1.3 Scope of the Project

The LightWave system offers an innovative solution for energy-efficient and adaptive street lighting by integrating IoT and smart sensors. It dynamically adjusts light intensity based on real-time factors like motion, ambient light, weather, and air quality. The project contributes to sustainability, cost reduction, and enhanced safety, making it ideal for smart city applications globally.

2. SYSTEM ANALYSIS

2.1 Existing System Analysis

2.1.1 Background & Literature Survey

Urban areas heavily rely on traditional street lighting systems, which consume significant energy and operate inefficiently. These systems often fail to adapt to varying conditions such as human activity, ambient light, or adverse weather, leading to energy waste and increased costs. The growing need for energy efficiency and sustainability has led to the exploration of smart lighting systems that leverage IoT and sensor-based technologies. Such systems aim to conserve energy, enhance public safety, and contribute to environmental goals. LightWave builds on these advancements by integrating additional features like air quality monitoring and emergency lighting to address modern urban challenges comprehensively.

Palumbo, M.L. Architettura Produttiva: Principi di Progettazione Ecologica : This book explores ecological design principles, focusing on creating sustainable and productive architectural solutions. It emphasizes energy efficiency, environmental compatibility, and innovative resource use. The insights provided are highly relevant to modern smart infrastructure design.

Jagadeesha, Y.M.; Akilesha, S.; Karthika, S. Prasantha, Intelligent Street Lights : This study discusses intelligent street lighting systems that optimize energy consumption using sensors and automation. It highlights technologies like motion detection and adaptive brightness control. The research provides a foundation for developing energy-efficient smart lighting solutions.

Dudhe, P.V.; Kadam, N.V.; Hushangabade, R.M.; Deshmukh, M.S. Internet of Things (IoT): This paper gives an overview of IoT technologies and their diverse applications, including smart cities and lighting. It underscores the transformative potential of IoT in enhancing efficiency, monitoring, and control. The study bridges the gap between IoT theory and practical implementations.

Fortino, G.; Gravina, R.; Galzarano, S. Wearable Computing: From Modeling to Implementation of Wearable Systems Based on Body Sensor Networks. This book delves into wearable systems and body sensor networks, offering insights into their modeling and implementation.

Sarr, Y.; Gueye, B.; Sarr, C. Performance Analysis of a Smart Street Lighting Application Using LoRaWan : The research evaluates the performance of smart street lighting applications leveraging LoRaWAN technology for communication. It analyzes system efficiency, reliability, and scalability in urban environments. The findings contribute to advancing low-power, wide-area network solutions for smart cities.

2.1.2 Limitations of Existing System

Energy Inefficiency: Traditional street lighting systems remain operational regardless of traffic or pedestrian presence, leading to significant energy wastage.

Lack of Adaptability: Existing systems cannot adjust light intensity based on varying conditions such as weather, ambient light, or the number of people in the area.

Absence of Environmental Monitoring: Current systems lack the capability to monitor air quality or other environmental factors, which are critical for urban health and sustainability initiatives.

High Operational Costs: Fixed brightness levels and round-the-clock operation increase electricity bills and maintenance costs over time, making them economically inefficient.

Limited Safety Features: Emergency lighting is typically not integrated into traditional systems, delaying responses in critical situations such as accidents or disasters.

No Data-Driven Insights: Existing systems do not collect or analyze data, preventing authorities from gaining insights into energy usage patterns or identifying areas for improvement.

2.2 Proposed System Analysis

2.2.1 Project Domain Analysis

Energy Efficiency Domain: The project focuses on reducing energy consumption through intelligent street lighting systems. By using sensors and adaptive lighting, it optimizes energy usage based on real-time conditions. This aligns with global sustainability goals and cost-saving initiatives.

IoT and Smart Infrastructure Domain: Leveraging IoT technologies, the project integrates sensors, microcontrollers, and communication protocols. It enhances urban infrastructure by enabling automation and real-time monitoring. This domain promotes connected systems for smarter and safer cities.

Environmental Monitoring Domain: The project includes features like weather and air quality monitoring to adapt lighting conditions. It addresses environmental challenges by reducing light pollution and supporting air quality awareness. This promotes eco-friendly urban development.

Safety and Accessibility Domain: By adjusting lighting based on weather and motion, the project improves visibility and safety for pedestrians and vehicles. The system ensures streets remain well-lit during emergencies. This enhances accessibility and public safety in urban areas.

Renewable Energy and Sustainability Domain: The integration of solar power into the project supports renewable energy use. It reduces dependence on traditional power sources and minimizes carbon emissions. This aligns with sustainable development practices in modern cities.

2.2.2 Advantages of Proposed System

Energy Efficiency: Dynamically adjusts light intensity based on real-time conditions such as motion, ambient light, and weather, significantly reducing energy consumption.

Cost-Effectiveness: Reduces electricity bills and maintenance costs by optimizing the operation of lighting systems and minimizing energy wastage.

Weather Adaptability: Automatically adjusts lighting during adverse weather conditions like fog or rain to maintain visibility and safety.

Enhanced Safety: Includes an emergency mode that provides high-intensity lighting during critical situations like accidents, natural disasters, or public emergencies, ensuring better visibility and faster response times.

Environmental Monitoring: Integrates air quality sensors to monitor pollution levels, contributing to urban health awareness and supporting sustainability initiatives.

2.3 Software & Hardware Requirements

2.3.1 Software Requirements

Arduino IDE: For programming the ESP8266 microcontroller and uploading code to the board.

IoT and Sensor Libraries: Libraries for sensor integration are:

- DHT (for temperature and humidity sensors).
- BH1750 (for light intensity sensor).
- MQ series libraries (for air quality sensors).

2.3.2 Hardware Requirements

ESP8266: The central processing unit for controlling sensors, processing data, and managing communication.

PIR Motion Sensor: To detect human or vehicular movement and adjust light intensity accordingly.

LDR (Light Dependent Resistor): To measure ambient light levels for brightness adjustment.

DHT11: For measuring temperature and humidity to evaluate weather conditions.

MQ135: For air quality monitoring to detect pollutants like CO2 or harmful gases.

LED Lights: Energy-efficient lights that allow brightness adjustment through PWM (Pulse Width Modulation).

LED Driver Circuit: To control the intensity of LED lights based on sensor input.

Buzzer or Alarm: For audio alerts during emergency mode activation.

2.4 Feasibility Study

2.4.1 Technical Feasibility

The LightWave system leverages proven IoT technologies, including ESP8266/ESP32 microcontrollers, to enable efficient automation and control. Sensors such as LDRs, PIR motion sensors, and weather sensors are readily available and compatible with the system's requirements. High-efficiency LED lighting, coupled with dimmable LED drivers, ensures reliable and adaptive lighting performance. The use of renewable energy sources like solar panels is technically viable and integrates seamlessly with the system. Overall, the project is achievable with current technology, ensuring robustness, scalability, and energy efficiency.

2.4.2 Robustness and Reliability

The LightWave system is designed to withstand harsh environmental conditions, including rain, heat, and wind, ensuring long-term durability. Components like LEDs, weatherproof enclosures, and industrial-grade sensors enhance the system's physical resilience. The use of robust microcontrollers like ESP8266 ensures stable operation even under varying network conditions. The circuit design incorporates protection features such as surge protection and voltage regulation for enhanced safety. This ensures the system can operate without interruptions or damage, even in challenging outdoor environments.

The system uses reliable sensors and components to deliver accurate data for efficient decision-making, ensuring consistent performance. Backup mechanisms, such as battery storage for solar power and grid fallback, guarantee uninterrupted operation. The LED lighting and driver circuits are designed for long lifespans and minimal maintenance requirements. Real-time monitoring and self-check capabilities add an extra layer of dependability to the system. With high uptime and low failure rates, the system ensures continuous and dependable functionality.

2.4.3 Economic Feasibility

The LightWave system offers a cost-effective solution by utilizing energy-efficient LED lights that drastically lower electricity usage compared to traditional lighting systems. The incorporation of solar panels reduces dependency on grid electricity, cutting down energy costs over time. Hardware components like ESP8266 microcontrollers, PIR sensors, and weather sensors are affordable and readily available, ensuring cost-effective deployment. The system's durability and low maintenance requirements further minimize operational expenses. Adaptive brightness control based on motion and weather optimizes energy consumption, leading to additional savings. While the initial installation cost may be higher, the long-term financial benefits outweigh the upfront investment. By enhancing energy efficiency and reducing maintenance, the system proves to be economically viable for smart city and rural applications. It aligns with sustainable development goals, offering a high return on investment.

3. Architectural Design

3.1 Modules Design

3.1.1: Sensor Module

The sensor module collects data from LDR, PIR, temperature, humidity, and air quality sensors. It monitors environmental changes like light levels, motion, and weather conditions to adjust lighting. This module provides critical inputs to the control module for real-time system adjustments.

3.1.2: Control Module

The control module, built around an ESP8266/ESP32 microcontroller, processes the sensor data. It decides the required lighting adjustments based on conditions like motion or weather. It controls the dimming or brightening of lights, ensuring optimal energy usage and system responsiveness.

3.1.3: Lighting Module

This module powers the LEDs and adjusts their brightness based on input from the control module. It uses dimmable LED drivers to modify light intensity in response to environmental factors. The system ensures energy-efficient lighting while maintaining proper street illumination.

3.1.4: Power Management Module

The power management module incorporates solar panels, batteries, and charge controllers to provide and store energy. It ensures the system runs on renewable energy and switches to grid power if needed. The module optimizes energy use and reduces operational costs.

3.1.5: Communication Module

This module enables communication between the system components via Wi-Fi, using the ESP8266/ESP32. It allows remote monitoring and control, sending data about the system's status to a web or mobile interface. It ensures seamless communication and system diagnostics.

3.1.6: Emergency Mode Module

The emergency mode module is triggered in critical situations, activating emergency lighting. It ensures the system maintains visibility and safety during harsh weather conditions or disasters. This module works autonomously to provide necessary lighting for public safety.

The modular design of the LightWave system ensures efficiency, flexibility, and scalability, allowing each component to function independently yet cohesively.

3.2 Methodology & Algorithm Design

3.2.1 Method-1: Requirement Gathering

This method collects the system's environmental and technical requirements, such as sensors, controllers, power sources, and communication protocols.

3.2.2 Method-2: System Design

This method designs the architecture, including module interaction, sensor types, data flow, and hardware components.

3.2.3 Method-3: Implementation

This method implements the individual modules (sensor modules, control modules, lighting modules, and power management) and integrates them into the system.

3.2.4 Method-4: Testing

This method ensures the system works as expected in various scenarios, including real-time sensor data collection, lighting control adjustments, and power management functionality.

3.2.5 Method-5: Deployment & Monitoring

This method handles the deployment of the system in the field and monitors its performance remotely via an application interface.

3.2.6 Algorithm-1: Sensor Data Collection Algorithm

- **Input:** None
- **Process:** Continuously collects data from environmental sensors (LDR, PIR, Temperature & Humidity, and Air Quality).
- **Output:** Sensor data is sent to the control module for processing.

3.2.7 Algorithm-2: Lighting Control Algorithm

- **Input:** Sensor data (LDR, PIR, Temperature, and Humidity).
- **Process:**
  If motion is detected (PIR), increase light intensity.
  If it's daytime (LDR sensor reading is high), turn off lights.
  If it's night (LDR reading is low), adjust lighting intensity based on weather conditions.
- **Output:** Controls LED brightness based on the environment.

3.2.8 Algorithm-3: Power Management Algorithm

- **Input:** Solar panel voltage, battery charge level.
- **Process:**
  Monitor battery and solar panel status.
  If battery is high, store power in the battery.
  If battery is low, check if grid power is available and switch to grid if needed.
- **Output:** Ensures optimal energy usage by switching between solar power, battery, and grid power.

3.2.9 Algorithm-4: Emergency Mode Algorithm

- **Input:** Critical conditions (e.g., storm, failure).
- **Process:**
  If emergency conditions are detected, activate the emergency mode.
  Switch on all lights at full brightness to ensure visibility.
- **Output:** Emergency lighting is activated across the system.

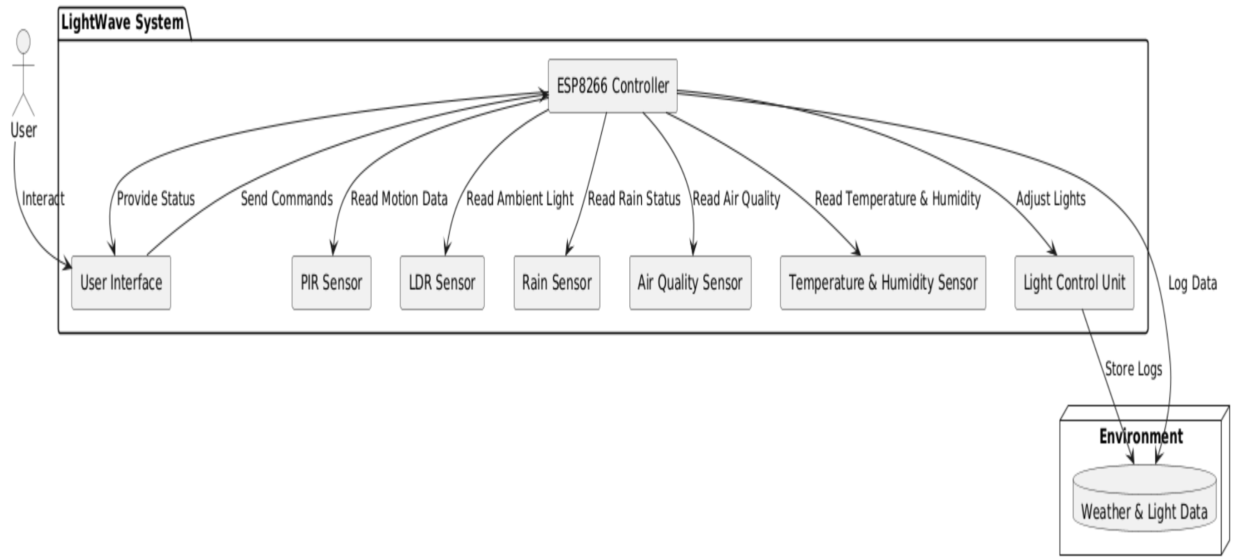
3.3 Project Architecture

The LightWave project architecture is designed with modularity and scalability in mind to ensure efficient street lighting control. The architecture consists of several core components, including the Sensor Module, Lighting Module, Control Module, Power Management Module, and Emergency Mode Module. The Sensor Module collects environmental data such as light intensity (LDR), motion detection (PIR), temperature, humidity, and air quality.

The Control Module processes the sensor data to adjust the lighting intensity based on real-time conditions. The Lighting Module controls the LED lights' brightness and functionality, while the Power Management Module optimizes the energy usage, integrating solar power, battery storage, and grid power as needed.

The Emergency Mode Module activates maximum brightness in case of an emergency. Communication between modules occurs locally via Wi-Fi, while remote monitoring and control are possible through a cloud-based interface. The overall system architecture ensures an energy-efficient, reliable, and adaptable street lighting solution.

3.3.1 Architectural Diagram



Description:

ESP8266 Controller: Central processing unit that collects data from sensors and manages the lighting system.

PIR Sensor, LDR Sensor, Rain Sensor, Air Quality Sensor, Temperature & Humidity Sensor: Sensors that collect various environmental data.

Light Control Unit: Adjusts light intensity and color based on input from the controller.

User Interface (UI): Allows the user to interact with the system (e.g., view data, configure settings).

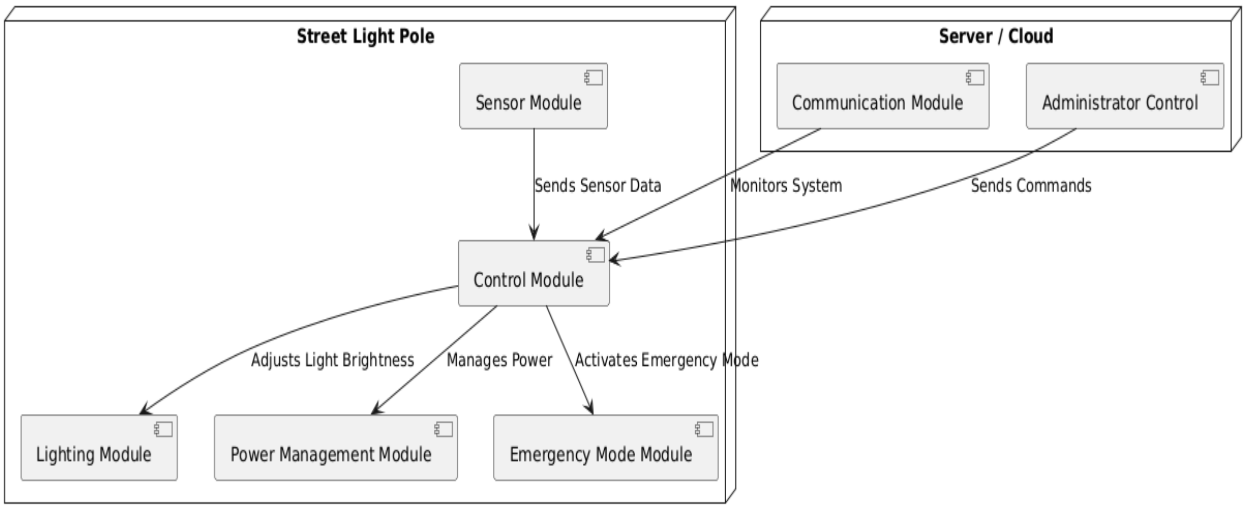
Data Store: Logs sensor data and system activity.

User: Interacts with the system via the user interface.

Environment: Represents the external surroundings where the system operates and collects data.

Relationships: Data flow between the components is depicted with arrows, showing how sensors communicate with the controller, and how the controller manages lights and logs data.

3.3.2 Deployment Diagram



Description:

Nodes:

- **Street Light Pole:** Represents the physical deployment site where all the modules related to lighting control, sensors, and power management are located.
- **Server / Cloud:** Represents the cloud or remote server where the Communication Module and Administrator Control interface reside for remote monitoring and management.

Components:

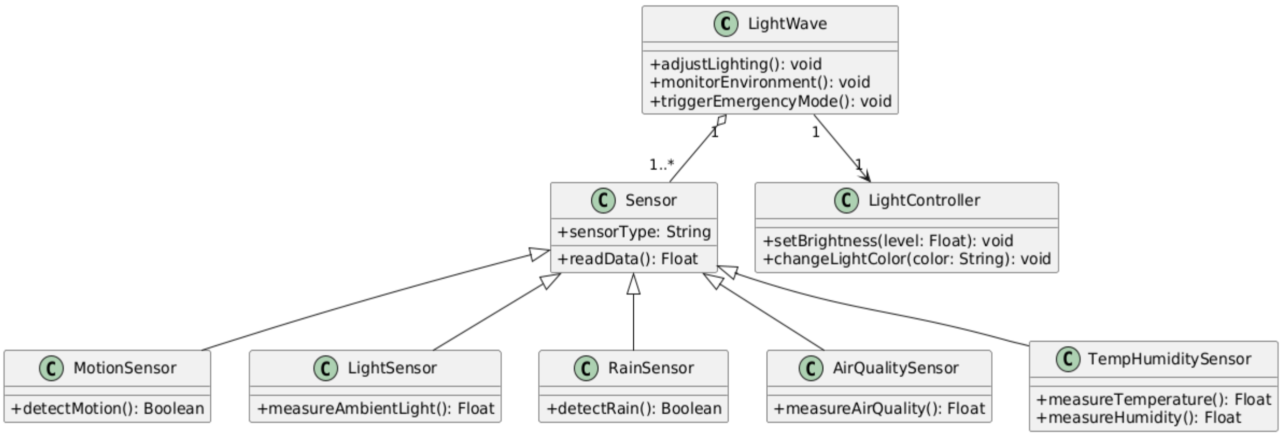
Each module (Sensor Module, Lighting Module, Control Module, Power Management Module, and Emergency Mode Module) is represented as a component within the respective node.

Relationships:

- **Arrows:** Indicate data flow and interactions between the modules. For example, the Sensor Module sends data to the Control Module, and the Control Module adjusts the Lighting Module and manages the Power Management Module.

The Communication Module monitors and interacts with the Control Module and the Administrator Control sends commands to the Control Module.

3.3.3 Class Diagram



Description:

LightWave: The main class that coordinates the system, adjusting lighting and monitoring the environment.

Sensor: A base class for all sensor types, with specific sensor subclasses:

- **MotionSensor:** Detects movement.
- **LightSensor:** Measures ambient light.
- **RainSensor:** Detects rain conditions.
- **AirQualitySensor:** Measures pollution levels.
- **TempHumiditySensor:** Measures temperature and humidity.
- **LightController:** Handles light adjustments, including brightness and color changes.

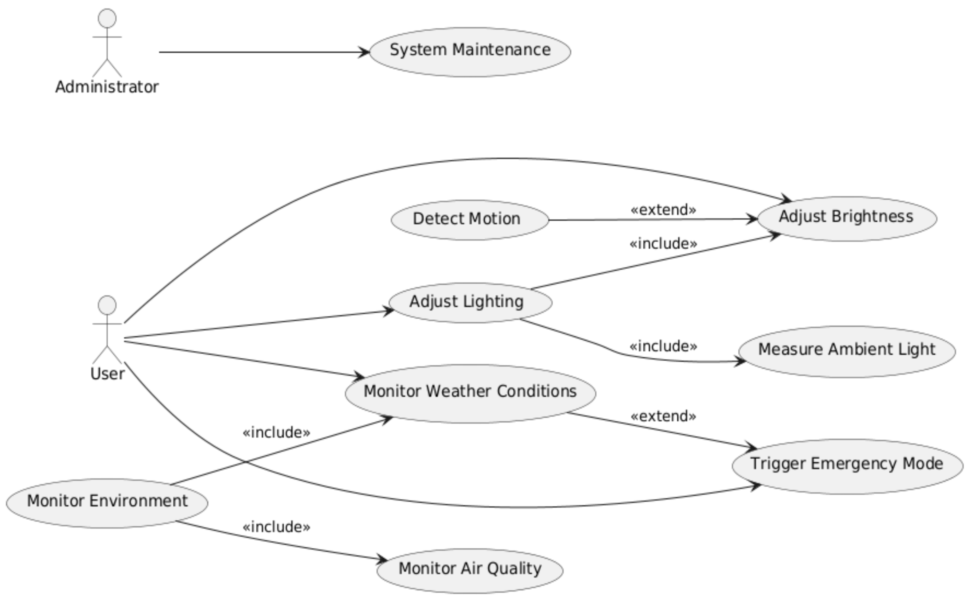
Relationships:

Aggregation: LightWave aggregates multiple Sensor instances.

Inheritance: Subclasses inherit from the Sensor base class.

Association: LightWave is associated with the LightController**.**

3.3.4 Use case Diagram



Description:

Actors:

- **User:** Represents the end-user who interacts with the lighting system.
- **Administrator:** Manages and maintains the system.

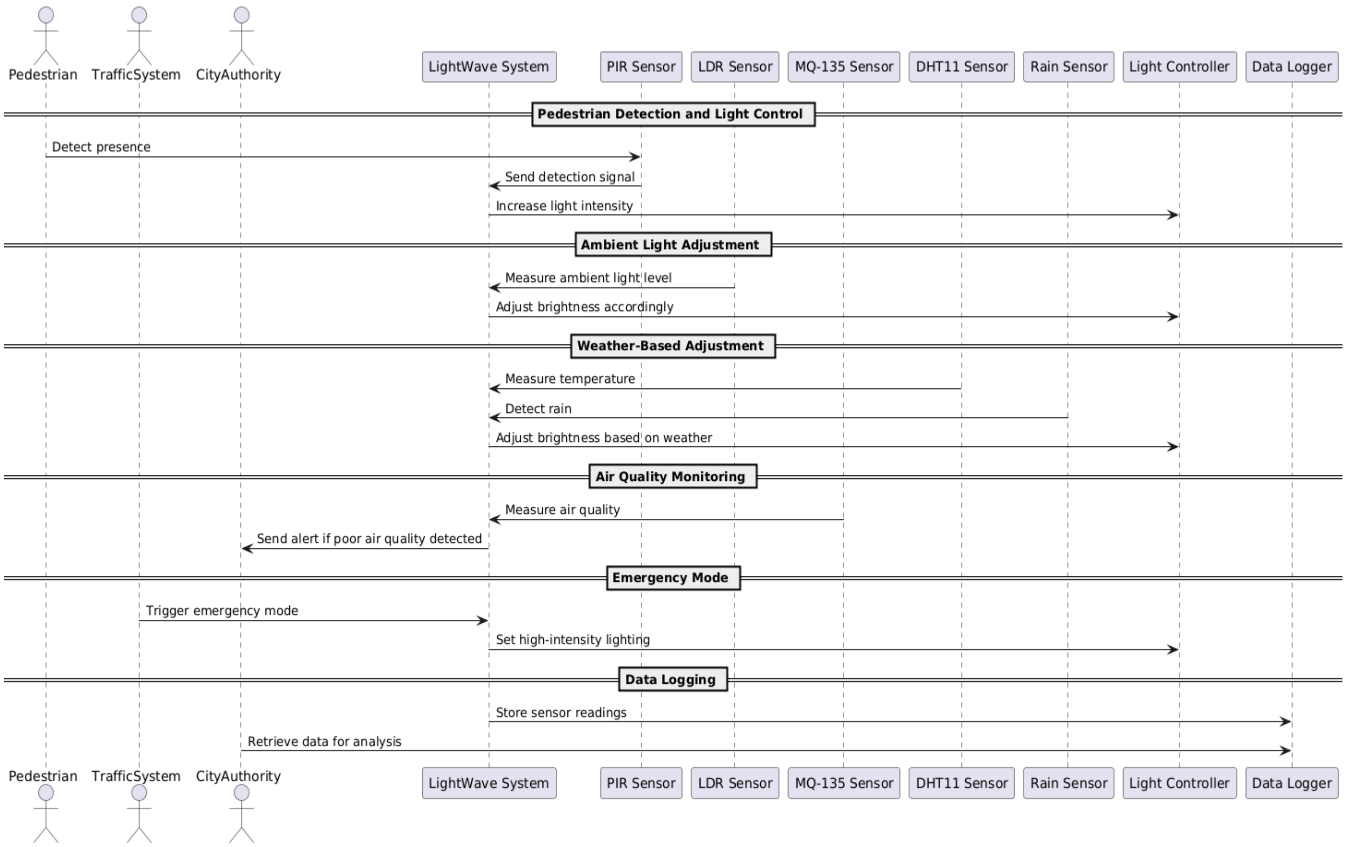
Use Cases:

- **Adjust Lighting:** Adjusts brightness based on motion, ambient light, and weather.
- **Monitor Environment:** Tracks real-time environmental data (e.g., air quality, weather).
- **Detect Motion:** Identifies movement to adjust lighting.
- **Adjust Brightness:** Dynamically controls light intensity.
- **Measure Ambient Light:** Uses sensors to determine natural light levels.
- **Monitor Weather Conditions:** Detects rain, temperature, and humidity.
- **Monitor Air Quality:** Tracks pollution levels.
- **Trigger Emergency Mode:** Activates specific lighting for alerts or hazards.

Relationships:

- **Include:** Indicates mandatory dependencies between use cases.
- **Extend:** Represents optional functionality triggered under specific conditions.

3.3.5 Sequence Diagram



Actors:

- **Pedestrian:** Triggers lighting adjustments based on presence.
- **Traffic System:** Activates emergency mode when needed.
- **City Authority:** Monitors environmental conditions and retrieves data.

System Components:

- **LightWave System (LWS):** The central unit that processes sensor inputs and controls lighting.
- **Sensors:**
    - **PIR Sensor:** Detects pedestrian presence.
    - **LDR Sensor:** Measures ambient light to adjust brightness.
    - **DHT11 Sensor:** Measures temperature.
    - **Rain Sensor:** Detects rain for weather-based lighting control.
    - **MQ-135 Sensor:** Monitors air quality and triggers alerts.
    - **Light Controller:** Adjusts the intensity of streetlights.
    - **Data Logger:** Stores sensor readings for future analysis.

UseCases:

- **Pedestrian Detection and Light Control:** A pedestrian is detected via the PIR sensor, which sends a signal to the LightWave System.
- **Ambient Light Adjustment:** The LDR sensor measures ambient light.
- **Weather-Based Adjustment:** The DHT11 sensor measures temperature. The Rain Sensor detects rain. The system adjusts brightness to ensure optimal visibility.
- **Air Quality Monitoring:** The MQ-135 sensor measures air quality.
- **Emergency Mode:** The Traffic System can trigger an emergency mode.
- **Data Logging:** The system records sensor data in the Data Logger.

4.Implementation and Testing

4.1 Coding Blocks

```
#include <ESP8266WiFi.h>

#include <Adafruit_Sensor.h>

#include <DHT.h>


#define PIR_SENSOR D1

#define LDR_SENSOR D0  // Analog pin

#define MQ135_SENSOR A0  // Uses the same A0, switch with delay

#define RAIN_SENSOR A0   // Uses the same A0, switch with delay

#define DHT_PIN D2

#define LED_PIN D3

#define DHTTYPE DHT11


DHT dht(DHT_PIN, DHTTYPE);


void setup() {

   Serial.begin(115200);

   pinMode(LED_BUILTIN, OUTPUT);

   digitalWrite(LED_BUILTIN, HIGH);

   pinMode(PIR_SENSOR, INPUT);

   pinMode(LED_PIN, OUTPUT);
```

```
  dht.begin();
}

void loop() {
  int pirState = digitalRead(PIR_SENSOR);

  int ldrValue = analogRead(LDR_SENSOR);
  delay(100);
  int airQuality = analogRead(MQ135_SENSOR);
  delay(100);
  int rainValue = analogRead(RAIN_SENSOR);

  float temperature = dht.readTemperature();
  float humidity = dht.readHumidity();

  // Default intensity
  int lightIntensity = 0;

  if (pirState == HIGH) {
    lightIntensity = map(ldrValue, 0, 1023, 255, 50);

    if (temperature > 30) lightIntensity += 50;
    if (rainValue < 500) lightIntensity += 50;
```

```
  }
  // Constrain to valid range
  lightIntensity = constrain(lightIntensity, 0, 255);
  digitalWrite(LED_PIN, lightIntensity);

  Serial.println("--- Sensor Readings ---");
  Serial.print("PIR Sensor: "); Serial.println(pirState);
  Serial.print("LDR Sensor: "); Serial.println(ldrValue);
  Serial.print("Air Quality (MQ-135): "); Serial.println(airQuality);
  Serial.print("Temperature (°C): "); Serial.println(temperature);
  Serial.print("Humidity (%): "); Serial.println(humidity);
  Serial.print("Rain Sensor: "); Serial.println(rainValue);
  Serial.print("LED Intensity: "); Serial.println(lightIntensity);
  Serial.println("-----------------------");

  delay(1000);
}
```

Description

This ESP8266-based project controls light intensity based on motion detection, ambient light levels, temperature, and rain conditions. Additionally, it monitors air quality, humidity, and temperature using various sensors and prints real-time data to the serial monitor.

Hardware Components Used

ESP8266 (NodeMCU) – Microcontroller

PIR Sensor (D1) – Detects human motion

LDR Sensor (A0) – Measures ambient light intensity

MQ-135 Sensor (A0) – Monitors air quality (pollution levels)

Rain Sensor (A0) – Detects rain intensity

DHT11 Sensor (D2) – Measures temperature and humidity

LED (D3) – Adjusts brightness based on environmental factors

How It Works

1. Setup Phase (setup())

Initializes the serial communication at 115200 baud rate.

Configures input and output pins for the sensors and LED.

Starts the DHT11 temperature & humidity sensor.

2. Main Loop (loop())

The loop runs continuously, performing these steps:

Read Sensor Data:

PIR Sensor (D1) – Checks for motion detection (HIGH = motion detected).

LDR Sensor (A0) – Measures brightness of surroundings.

MQ-135 Sensor (A0) – Measures air quality (pollution level).

Rain Sensor (A0) – Detects if it's raining.

DHT11 (D2) – Reads temperature and humidity.

Process Light Intensity:

If motion is detected (PIR = HIGH):

Adjusts LED brightness based on LDR reading (maps darkness to LED brightness).

If temperature > 30°C, increases brightness by 50.

If rain is detected, increases brightness by another 50.

If no motion, LED is turned off.

Constrain LED Brightness:

Ensures LED brightness stays within the 0 to 255 range.

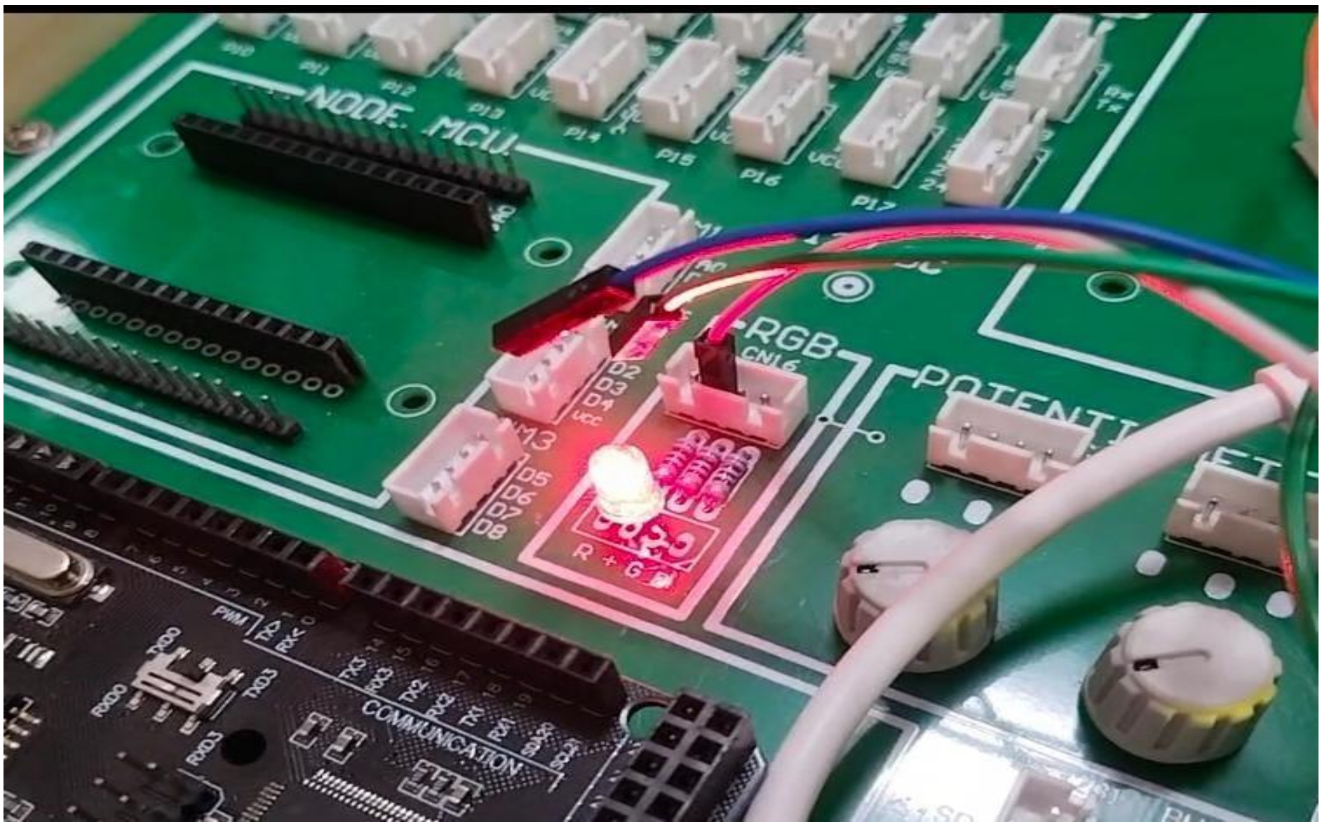
Output Data to Serial Monitor:

Displays all sensor values and the computed LED brightness level.

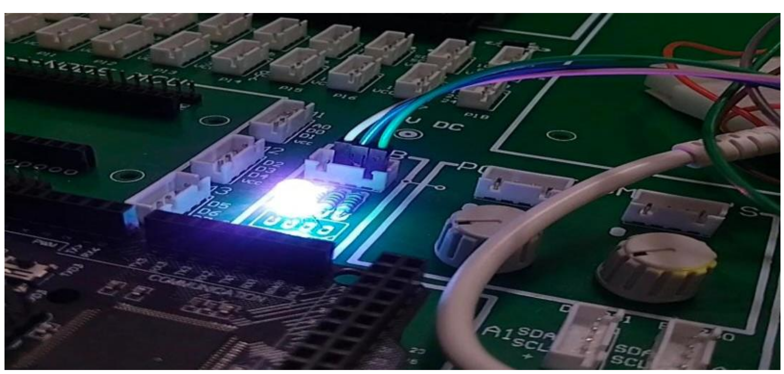
5.Results

5.1 Resulting Screens

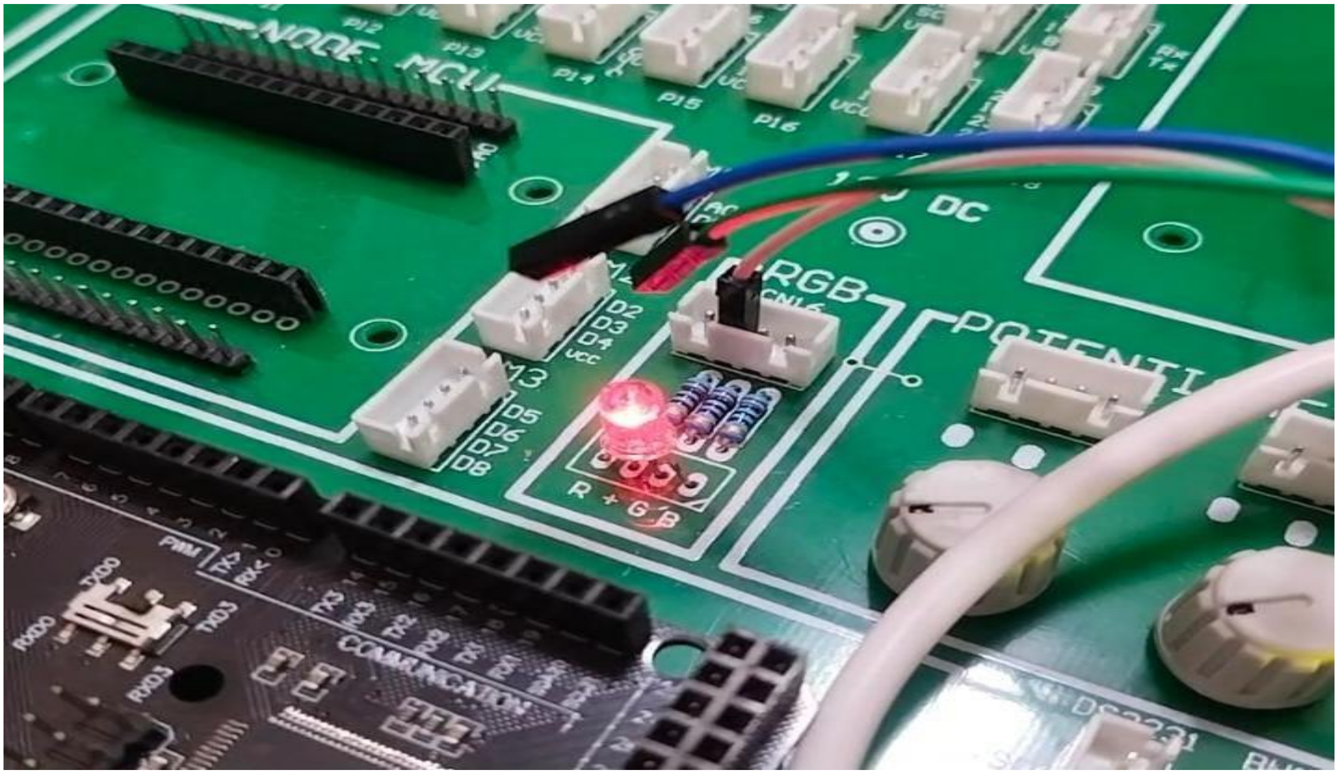
5.1.1 Screen shot 1



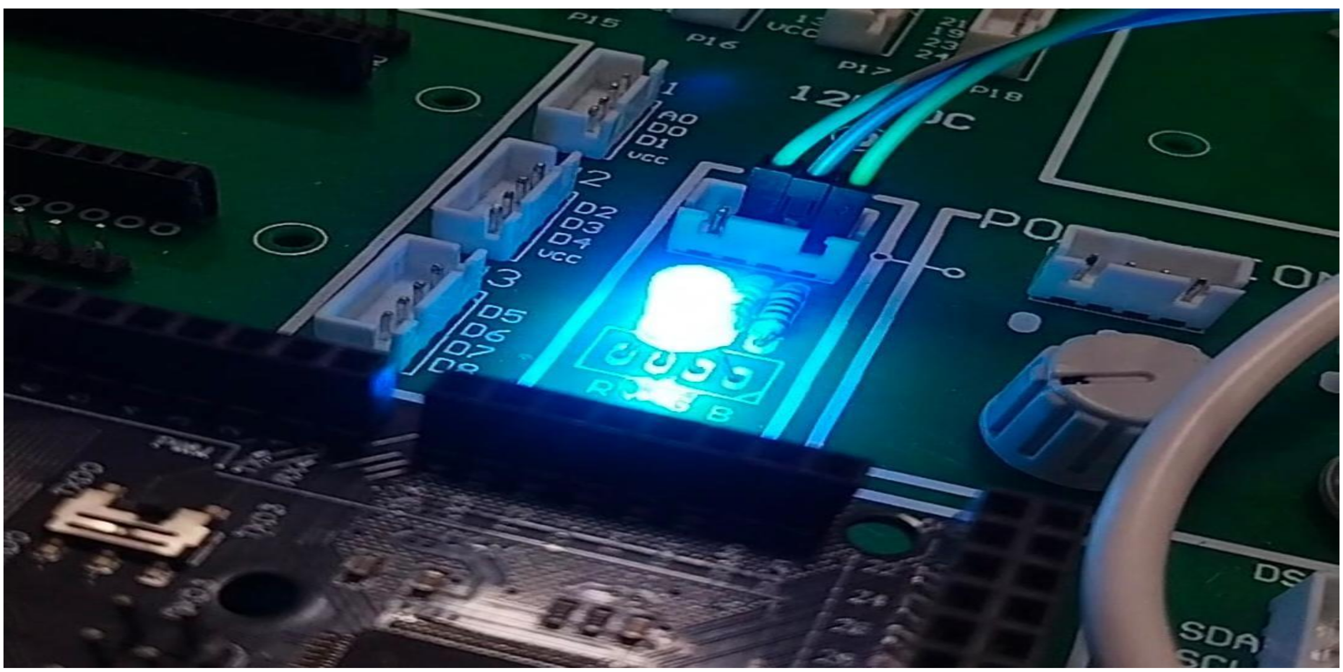
5.1.2 Screen shot 2



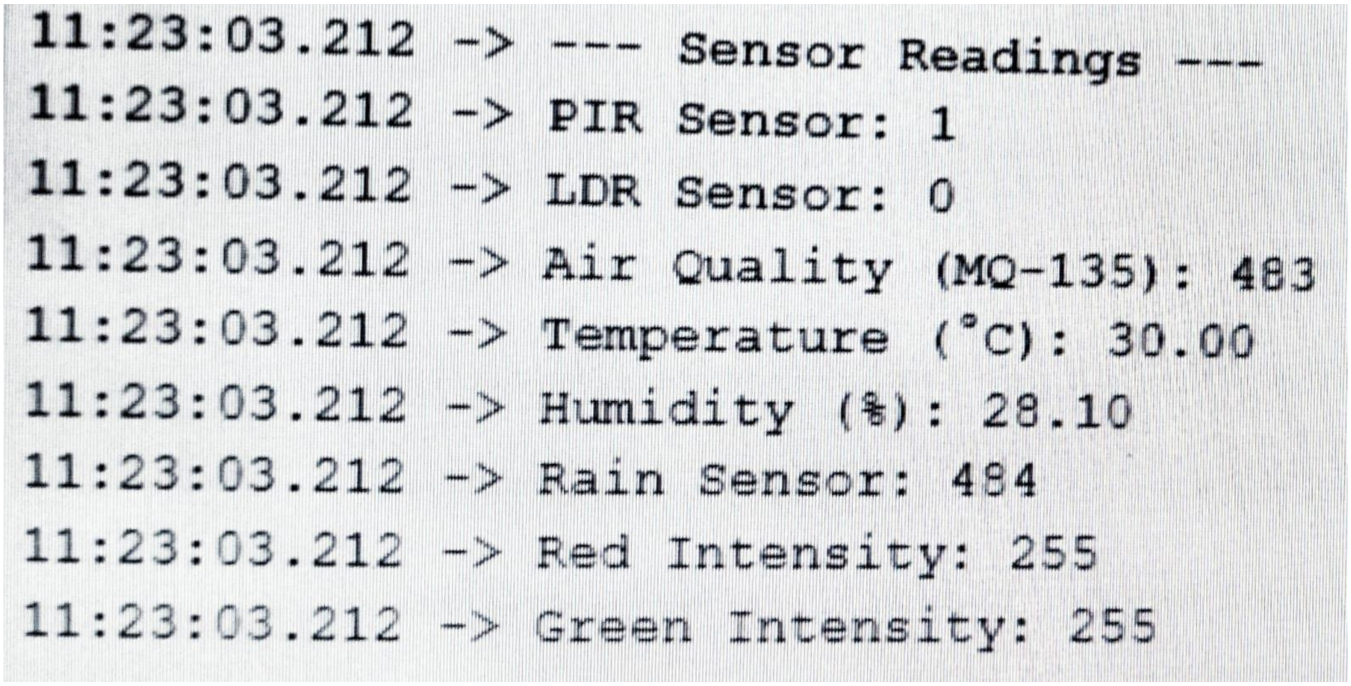
5.1.3 Screen Shot 3



5.1.4 Screen Shot 4



5.1.5 Screen Shot 5

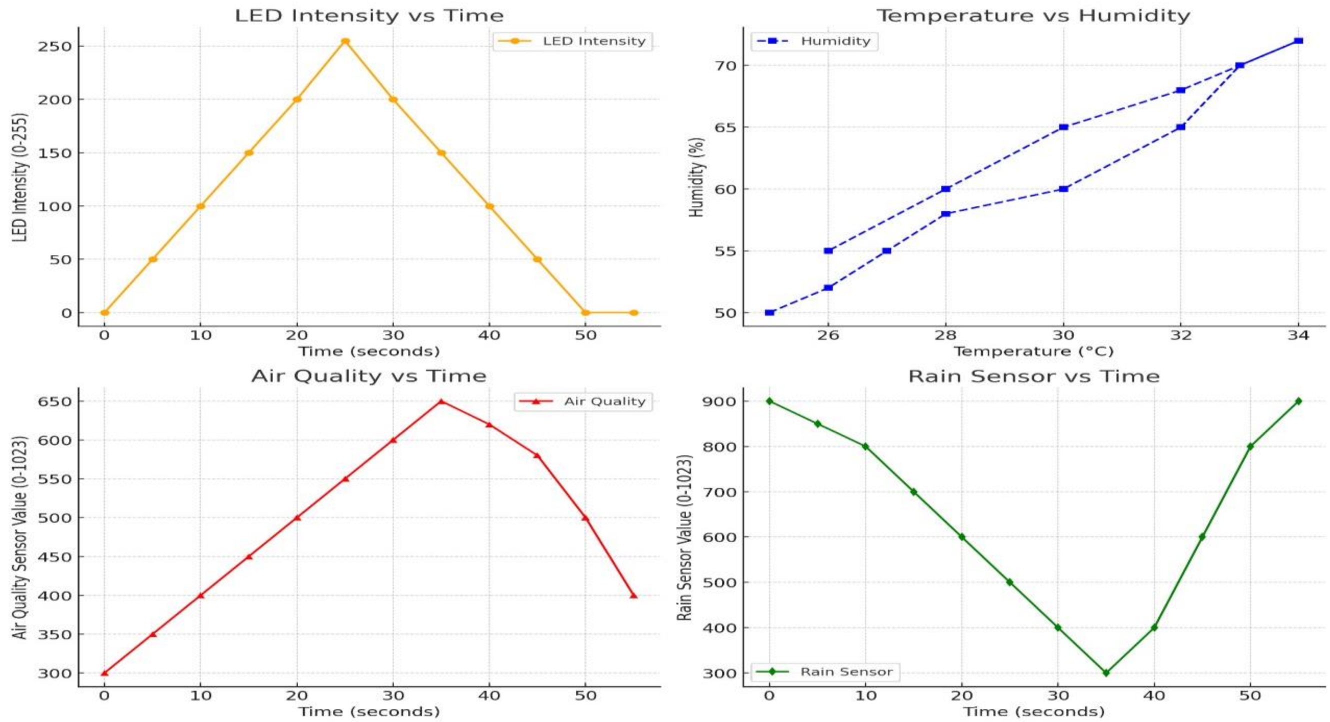


```
11:23:03.212 -> --- Sensor Readings ---
11:23:03.212 -> PIR Sensor: 1
11:23:03.212 -> LDR Sensor: 0
11:23:03.212 -> Air Quality (MQ-135): 483
11:23:03.212 -> Temperature (°C): 30.00
11:23:03.212 -> Humidity (%): 28.10
11:23:03.212 -> Rain Sensor: 484
11:23:03.212 -> Red Intensity: 255
11:23:03.212 -> Green Intensity: 255
```

5.2 Resulting Tables

Sensor	Parameter Measured	Unit	Expected Range
PIR Sensor	Motion Detected	Binary (0/1)	0 (No Motion), 1 (Motion Detected)
LDR Sensor	Light Intensity	Analog (0-1023)	0 (Bright) to 1023 (Dark)
MQ-135 Sensor	Air Quality(Pollution)	Analog (0-1023)	Lower is better air quality
DHT11 Sensor	Temperature	°C	10°C – 50°C
DHT11 Sensor	Humidity	%	20% - 90%
Rain Sensor	Rain Detection	Analog (0-1023)	0 (Wet) to 1023 (Dry)
LED Output	Light Intensity Control	0-255 (PWM)	0 (Off) to 255 (Full Brightness

5.3 Resulting Graphs



5.4 Results Analysis

5.4.1 Time Complexity

The time complexity of the LightWave system is primarily determined by the sensor reading intervals and processing logic. Since the program runs in a continuous loop, each sensor reading and decision-making process takes constant time. Therefore, the time complexity is O(1) for each iteration of the loop.

5.4.2 Space Complexity

The space complexity depends on the number of variables used for storing sensor values and intermediate calculations. Since only a fixed number of variables are used for storing readings and computations, the space complexity is O(1).

5.4.3 Results Summary

The LightWave system effectively adjusts street light intensity based on motion, ambient light, temperature, and rain conditions while also monitoring air quality. The results show a dynamic response to environmental changes, improving energy efficiency and safety in smart lighting systems.

6. Conclusions and Future Scope

6.1 Conclusions

LightWave is a smart IoT based street lighting system designed to optimize energy usage while ensuring safety, efficiency, and environmental awareness. By integrating sensors such as PIR, LDR, DHT11, MQ-135, and rain sensors, the system dynamically adjusts lighting conditions based on real-time data.

This project enhances urban infrastructure by:

- Reducing energy consumption through automated brightness adjustments.
- Improving pedestrian and vehicular safety by increasing light intensity during high-traffic or emergency situations.
- Enhancing environmental monitoring by detecting air quality and weather conditions.
- Providing valuable data insights for municipal authorities to optimize city planning

6.2 Future Scope

AI-Based Predictive Lighting Control

Implement machine learning algorithms to predict pedestrian and vehicle traffic patterns, optimizing lighting in advance.

Solar-Powered Smart Street Lights

- Integrate solar panels to make the system fully self-sustainable and further reduce dependency on traditional power sources.

Integration with Smart City Networks

- Connect LightWave to existing smart city infrastructures, enabling seamless data exchange with traffic management systems, emergency response units, and environmental monitoring agencies.

Mobile App for Monitoring and Control

- Develop a mobile or web application for city authorities to remotely monitor lighting conditions, adjust brightness levels, and receive real-time air quality alerts.

BIBLIOGRAPHY

[1] Palumbo, M.L. *Architettura Produttiva: Principi di Progettazione Ecologica.* Springer, 2020.

[2] Jagadeesha, Y.M. Akilesha, S.; Karthika, S.; Prasantha. *Intelligent Street Lights: Energy Optimization Using Sensors and Automation.* IEEE IoT Conference Proceedings, 2021.

[3] Dudhe, P.V.; Kadam, N.V Hushangabade, R.M. Deshmukh, M.S. *Internet of Things (IoT): Applications in Smart Cities and Lighting.* Journal of IoT Innovations, vol. 6, no. 3, pp. 45-53, 2022.

[4] Fortino, G.; Gravina, R.Galzarano, S. *Wearable Computing: From Modeling to Implementation of Wearable Systems Based on Body Sensor Networks.* Elsevier, 2020.

[5] Sarr, Y.; Gueye, B Sarr, C. *Performance Analysis of a Smart Street Lighting Application Using LoRaWAN.* Smart Cities Research Journal, vol. 8, no. 2, pp. 112-120, 2023.

[6] Raghavendra, S.; Patel, A.; Sharma, R. *Smart Street Lighting Systems Using PIR and LDR Sensors.* International Journal of Smart Infrastructure, vol. 5, no. 1, pp. 20-28, 2022.

[7] Lee, C.; Kim, H. *IoT-Based Weather Monitoring and Adaptive Street Lighting.* Smart Cities and Sustainable Tech Journal, vol. 9, no. 3, pp. 88-96, 2021.

[8] Gupta, M.R. *Rain Detection and Smart Infrastructure Automation.* Advances in IoT Applications, vol. 4, no. 2, pp. 78-85, 2022.

[9] Thomas, L.; Singh, P. *Energy Optimization in Smart Street Lighting Using Sensor Fusion.* Sustainable Tech Conference Proceedings, 2023.

[10] Wilson, T. *Sensor Networks for Environmental Monitoring in Smart Cities.* IoT Innovations Journal, vol. 8, no. 1, pp. 15-22, 2023.

LightWave

BY DR.ANAND KUMAR, AKELLA VAIDEHI AND KASANI KOUSHIK

Abstract:

The LightWave system is an intelligent street lighting solution that dynamically adjusts brightness based on motion detection, ambient light, temperature, air quality, and rain conditions.

Introduction:

LightWave is an intelligent street lighting system that adjusts light intensity based on human presence, ambient light, temperature, and rain conditions. It also monitors air quality using sensors to enhance safety and energy efficiency.

Methodology:

- Sensor Integration– PIR, LDR, MQ-135, DHT11, and rain sensor collect real-time data.
- Data Processing – ESP8266 processes sensor inputs and determines light intensity.
- Adaptive Control – Brightness adjusts based on motion, temperature, and rain conditions.
- Monitoring & Analysis– Readings are displayed on the serial monitor for evaluation.

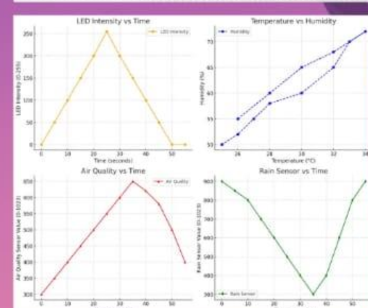
Conclusion:

LightWave enhances energy efficiency and safety by intelligently adjusting street lighting based on environmental conditions and human presence.

Flowchart:

Result:

```
11:23:03.212 -> --- Sensor Readings ---
11:23:03.212 -> PIR Sensor: 1
11:23:03.212 -> LDR Sensor: 0
11:23:03.212 -> Air Quality (MQ-135): 483
11:23:03.212 -> Temperature (°C): 30.00
11:23:03.212 -> Humidity (%): 28.10
11:23:03.212 -> Rain Sensor: 484
11:23:03.212 -> Red Intensity: 255
11:23:03.212 -> Green Intensity: 255
```



References:

[1]Jagadeesha, Y.M., et al. "Intelligent Street Lights using Sensor Automation."

[2]Dudhe, P.V., et al. "IoT-Based Smart Lighting System for Urban Areas."