Prediction-based smart street lighting and environmental monitoring system using IoT and cloud

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***Abstract*—Smart Street lighting systems are increasingly being adopted to optimize energy usage. These systems automatically control street lights based on ambient light levels, ensuring they are only on when needed. This automation not only conserves energy but also reduces operational costs and manual intervention. Data collected from light sensors can be stored in the cloud, allowing the local authorities to monitor and analyze lighting patterns. This system contributes to smarter infrastructure and helps in reducing energy waste.**

The work addresses the limitations of existing smart street lighting systems, which typically rely on basic sensors for ambient light detection and often lack comprehensive environmental monitoring. To overcome these limitations, we are developing an advanced system that integrates additional sensors, including temperature, humidity, and MQ-135 air pollution sensors. The data collected from these sensors will be stored in the cloud and processed using machine learning algorithms to predict future environmental conditions. This approach enables a more efficient and intelligent system, combining hardware components like sensors and microcontrollers with software components for cloud storage and analytics, resulting in a robust and versatile solution.

***Index Terms*—Environmental Monitoring, Ambient Light Control, IoT Sensors, ThingSpeak Cloud, Data Representation, LSTM Model, Future Value Prediction, Machine Learning in IoT, Energy Efficiency, Real-Time Monitoring, Intelligent Lighting System.**

I. INTRODUCTION

Smart street lighting is an effective solution to reduce energy consumption in urban areas. Traditional street lights often operate inefficiently, leading to unnecessary energy usage. To address this, our project proposes a System that adjusts street lights based on ambient light conditions. In addition to controlling street lighting, the system monitors temperature**,** humidity, and air pollution using IoT sensors. The collected data is stored and displayed on ThingSpeak Cloud for real-time monitoring.

The system uses an LSTM model to predict future values of environmental parameters.

This predictive approach enables proactive management of street lighting and environmental conditions.it will also alert the neighbourhood with a buzzer when there is extreme temperature and high pollution. By integrating **s**mart lighting with environmental monitoring and machine learning, the proposed system improves energy efficiency and contributes to smart city solutions**.**

Figure 1

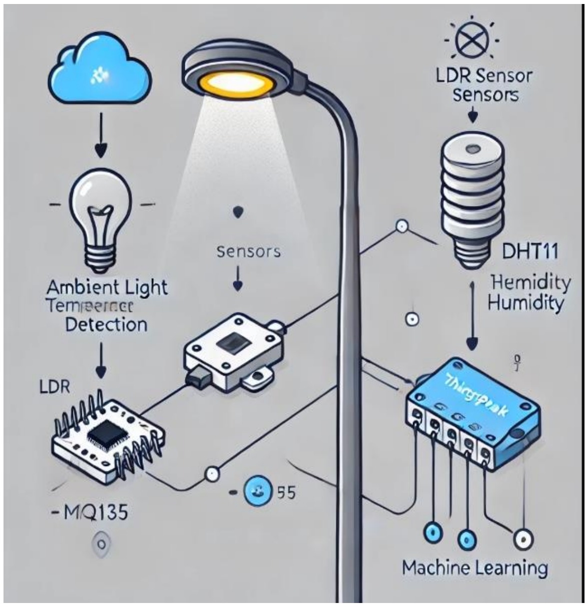
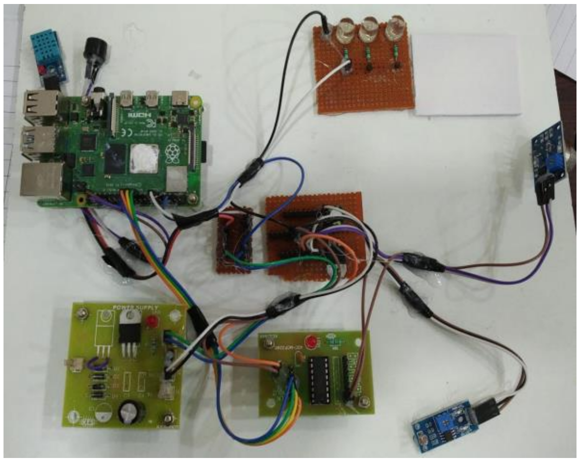


Figure 2



II LITERATURE SURVEY

1. Smart Street Lighting Systems in India Chavan et al. (2019) explored automatic street lighting systems using LDR sensors to adjust brightness based on ambient light, reducing energy consumption by 40%. This approach is crucial for smart city initiatives aimed at energy efficiency. Fathima Dheena et al. (2023) implemented an IoT-based smart street lighting system in India that senses ambient light and adjusts lighting accordingly. This system uses real-time data for efficient energy management and monitoring (IRJET).

2. IoT Integration for Environmental Monitoring Sharma et al. (2020) demonstrated the use of sensors to monitor temperature, humidity, and air quality, with data stored and visualized on cloud platforms like ThingSpeak. This system enables real-time monitoring and decision-making. Patel et al. (2021) integrated IOT with environmental sensors to create a smart monitoring system, enhancing urban management through real-time data analysis and visualization.

3. Cloud-Based Data Storage and Visualization ThingSpeak is widely used for cloud storage and data visualization in environmental monitoring systems. It enables real-time graphing and analysis, making it suitable for IoT applications. Studies have shown that using cloud platforms improves remote monitoring and data accessibility, enhancing decision-making processes.

4. Predictive Analysis Using LSTM Models Wang et al. (2018) highlighted the efficiency of LSTM models in time-series prediction due to their ability to learn from sequential data. They outperformed traditional algorithms in predicting environmental parameters. In India, Patel et al. (2021) used LSTM models to predict future environmental values, contributing to proactive urban management and resource allocation.

5. Energy Efficiency and Smart City Applications Kumar et al. (2022) emphasized the role of smart street lighting in reducing energy consumption and carbon emissions, aligning with India's sustainability goals. Tata Communications deployed smart street lighting solutions in cities like Noida and Ahmedabad, enabling remote monitoring and significant energy savings (Tata Communications).

6. Machine Learning in Smart Cities Citation: Bansal, A., & Kumar, R. (2022). Role of machine learning in smart city applications: A systematic review. Sustainable Cities and Society, 81, 103872.
this systematic review examines the application machine learning techniques in various smart city initiatives.

The authors highlight the effectiveness of
algorithms like Long Short-Term Memory (LSTM) networks in analyzing time-series data and predicting urban environmental conditions. The paper discusses the challenges associated with data integration and model training, advocating for improved algorithms and more comprehensive datasets to enhance the performance of smart city solutions.

7. Intelligent Street Lighting Systems Citation: Dey, S., & Gupta, A. (2020). A survey on smart street lighting systems: Challenges and opportunities. Journal of Ambient Intelligence and Humanized Computing, 11(4), 1591-1610.This survey provides a comprehensive overview of smart street lighting systems, discussing various technologies, including IOT, sensors, and cloud computing. The authors analyze the benefits of intelligent lighting solutions, such as energy savings and improved public safety, while also addressing challenges like data privacy, integration, and system scalability.

III. EXISTING WORK

1. Fixed Schedule Street Lighting Systems:

Tradditional street lighting systems typically operate on fixed schedules or manual controls, leading to inefficient energy consumption. These systems are unable to adapt to real-time environmental changes, resulting in unnecessary power usage during low-traffic hours.

2. Basic Sensors without Predictive Analytics:

Most existing methods rely on basic sensors for environmental data collection. However, they do not incorporate predictive analytics or cloud-based data processing for real-time decision-making or resource optimization.

3. Simple environmental Monitoring Systems:

Current environmental monitoring systems generally function independently, collecting data without integrated analysis or predictive features. These systems primarily gather information on light intensity, air quality, and temperature but lack advanced analytics for decision-making.

4. Limited Real-Time Decision-Making Capabilities:

Conventional systems are designed to provide static data without utilizing machine learning or IoT integration for real-time monitoring and adaptive control, limiting their effectiveness in dynamic urban environments.

Figure 3

```python
# Define sensor and actuator pins
LDR_PIN = 0  # LDR connected to ADC channel 0
MQ135_PIN = 1  # Air quality sensor to ADC channel 1
DHT_PIN = 4  # DHT11 connected to GPIO 4
LIGHT_PIN = 27  # Street light control
BUZZER_PIN = 17  # Buzzer alert

# Setup GPIO
GPIO.setmode(GPIO.BCM)
GPIO.setup(LIGHT_PIN, GPIO.OUT)
GPIO.setup(BUZZER_PIN, GPIO.OUT)

dht = Adafruit_DHT.DHT11
spi = spidev.SpiDev()
spi.open(0, 0)
spi.max_speed_hz = 1350000

def read_adc(channel):
    adc = spi.xfer2([1, (8 + channel) << 4, 0])
    return ((adc[1] & 3) << 8) + adc[2]

while True:
    # Read sensor values
    ldr_value = read_adc(LDR_PIN)
    air_quality = read_adc(MQ135_PIN)
    humidity, temperature = Adafruit_DHT.read(dht, DHT_PIN)

    # Print sensor values
    print("Light:", ldr_value)
    print("Air Quality:", air_quality)
    print("Humidity:", humidity)
    print("Temperature:", temperature)

    # Control street light
    if ldr_value < 300:
        GPIO.output(LIGHT_PIN, GPIO.HIGH)
    else:
        GPIO.output(LIGHT_PIN, GPIO.LOW)
```

IV PROPOSED SYSTEM

1. Smart Lighting Control:

Utilizes Light Dependent Resistor (LDR) sensors to measure ambient light levels, dynamically adjusting street lighting based on real-time environmental conditions. Enhances pedestrian safety while optimizing energy consumption by automatically controlling street lights.

2. cloud integration and predictive analytics

Data from the sensors is continuously uploaded to a cloud platform for centralized storage and processing. Employs Long Short-Term Memory (LSTM) networks to analyze historical and real-time data, predicting future environmental conditions like air quality, temperature, humidity, and light intensity.

3. Comprehensive Environmental Monitoring:

Uses DHT11 sensors to measure temperature and humidity providing a detailed environmental profile of the area. Deploys MQ135 sensors for air quality monitoring, detecting pollutants such as CO2 and other harmful gases.

4. Dynamic Decision-Making and Energy:

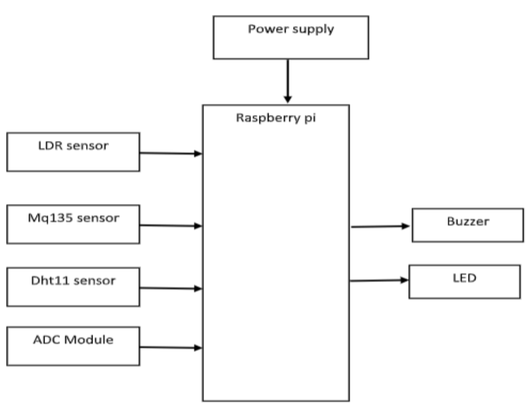
The system uses predictive insights to make proactive decisions, adjusting street lighting according to forecasted conditions, thus minimizing energy wastage.

The proposed system is an Integrated Prediction-Based Smart Street Lighting and Environmental Monitoring System that uses IoT sensors and cloud computing to make urban lighting smarter and more efficient. It adjusts street lights automatically based on real-time conditions and predictions, improving safety and saving energy. Light Dependent Resistor (LDR) sensors measure ambient light, while MQ135 sensors monitor air quality, and DHT11 sensors track temperature and humidity. All this data is sent to the cloud, where Long Short-Term Memory (LSTM) networks analyze it to predict future condition. This approach not only saves energy but also helps maintain a safer and more sustainable urban environment. Additionally, the system provides real-time monitoring and alerts, enabling quick responses to environmental changes. It also supports remote management through a cloud-based dashboard, allowing city administrators to make data-driven decisions. The predictive analytics feature helps in preventive maintenance, reducing operational costs and extending the lifespan of street lighting infrastructure. Furthermore, the system includes a buzzer alert that activates when air quality levels exceed safety thresholds, providing immediate warnings for hazardous environmental conditions.

V. DESIGN METHODOLOGY

1. Requirement Analysis:
Identifying the system's functional and non-functional requirements, including real-time environmental monitoring, predictive analytics, smart lighting control, and alert mechanisms.
2. Sensor Selection and Integration:
Choosing appropriate sensors such as LDR for ambient light, MQ135 for air quality, DHT11 for temperature and humidity. Integrating these sensors with microcontroller boards like Raspberry Pi for data collection and processing.
3. Data Acquisition and Transmission:
Collecting real-time data from sensors and transmitting it to the cloud using IoT communication protocols. The Raspberry Pi acts as a gateway, sending data to a cloud platform like ThingSpeak for storage and analysis.
4. Predictive Analytics using LSTM:
Implementing Long Short-Term Memory (LSTM) neural networks to analyze historical and real-time data, predicting future conditions like light intensity, air quality, temperature, and humidity. These predictions help in proactive decision-making.

Block diagram



5. Cloud Integration and Data Storage:
Storing environmental data on the cloud for real-time monitoring and historical analysis. Using cloud services to manage data storage, processing, and security.

6. Smart Lighting Control Mechanism:
Utilizing the predictions to dynamically adjust street lights based on ambient light conditions. Lights are in ON or OFF state as needed, optimizing energy consumption.

7. Alert System Integration:
Incorporating a buzzer alert that activates when air quality and temperature exceeds safety thresholds, ensuring immediate warnings for hazardous conditions.

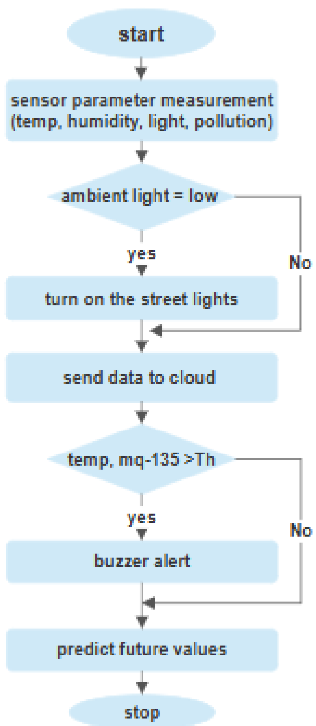
8. Dashboard and Remote Management:
Developing a cloud-based dashboard for real-time data visualization and remote management. This enables city administrators to monitor environmental parameters and street lighting status.

9. Testing and Optimization:
Conducting functional and performance testing to ensure system reliability, accuracy, and efficiency. Optimizing the LSTM model and system component for improved predictions and energy management.

10. Deployment and Maintenance:
Deploying the system in a real-world urban environment and performing regular maintenance for sensors and cloud components.
The design methodology for the Prediction-Based Smart Street Lighting and Environmental Monitoring System integrates energy-efficient sensors and advanced communication protocols to ensure reliable data transmission and minimal power consumption. It utilizes LDR sensors for ambient light detection, MQ135 for air quality monitoring and DHT11 for temperature and humidity measurement. These sensors are connected to Raspberry Pi boards, which transmit data to the cloud using secure communication protocols, ensuring data integrity and privacy. The system employs Long Short-Term Memory (LSTM) networks for predictive analytics, enabling accurate forecasting of environmental conditions and optimizing street lighting accordingly. It dynamically

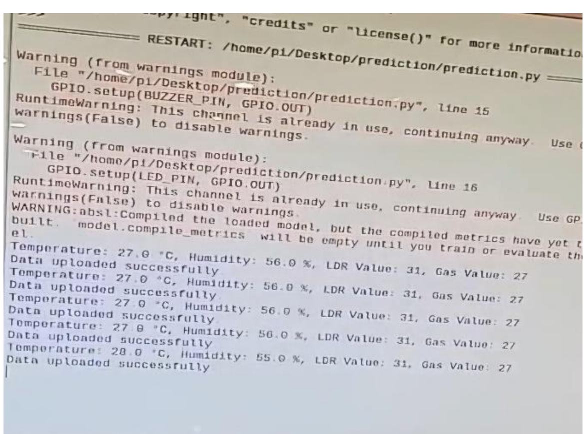
controls street lights based on real-time data and promotes energy efficiency and enhances pedestrian safety. Additionally, the system includes a buzzer alert for hazardous air quality, ensuring immediate notifications. A cloud-based dashboard allows remote monitoring and management, supporting scalability for future expansions.

Flowchart



VI. RESULT

Figure 4



The Prediction-Based Smart Street Lighting and Environmental Monitoring System efficiently measures ambient light, air quality, temperature, and humidity using LDR, MQ135, and DHT11 sensors**.** It uses LSTM networks to predict environmental conditions, enabling dynamic street light adjustments that save energy while maintaining safety. The system provides buzzer alerts for hazardous air quality and features a cloud-based dashboard for real-time monitoring and remote management. Testing showed significant energy savings and improved environmental awareness, making it an effective solution for sustainable urban lighting and resource management.

Figure 5

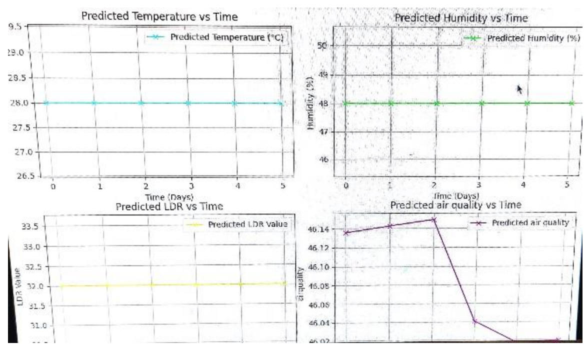


Figure 6

VII. CONCLUSION

The Prediction-Based Smart Street Lighting and Environmental Monitoring System represents a significant advancement in urban infrastructure, utilizing IoT and machine learning technologies to create a more efficient and responsive environment. By integrating various sensors to monitor light intensity, pedestrian movement, and environmental conditions, the system optimizes street lighting and enhances public safety. The application of Long Short-Term Memory (LSTM) networks for predictive analytics allows for proactive adjustments based on real-time data, promoting energy conservation and urban sustainability. This innovative approach not only improves the quality of urban life but also provides critical insights for future urban planning and development.

REFERENCES

[1] Khan, M. A., & Rehman, A. (2021). Internet of Things (IoT) based smart street lighting systems: A review. IEEE Access, 9, 110357-110372.

[2] Rahman, M. S., & Rahman, M. A. (2020). Smart environmental monitoring using IoT: A review of challenges and opportunities. Journal of Environmental Management, 269, 110763.

[3] Yu, H., & Xu, C. (2022). Machine learning in smart city applications: Opportunities and challenges. Future Generation Computer Systems, 125, 83-93.

[4] Alavi, M., & Sadeghi, A. (2021). Intelligent street lighting: An IoT approach. Sensors, 21(3), 1023.

[5] 1. **Waghmare, S. T., & Sonavane, S. S. (2019). ** A study on IoT-based smart street light systems. *International Conference on Smart City and Emerging Technology (ICSCET)*, 1-5.

[6] Rahman, M. A., Islam, M. S., & Hossain, M. A. (2022). ** An energy efficient IoT-based smart street lighting using low-cost system on chip (SoC). *IEEE International Conference on Robotics, Automation, Artificial Intelligence, and Internet of Things (RAAIIoT)*, 150-156.

[7] Singh, S. K., & Singh, A. K. (2023). ** IoT & vision-based environment monitoring system. *IEEE International Conference on Electronics, Computing, and Communication Technologies (CONECCT)*, 234-239.