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Major Project Phase 1 Report on

"Design of the Urban Lighting Control System"

Submitted in partial fulfilment of the requirements for the award of the degree of

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ELECTRONICS AND COMMUNICATION ENGINEERING

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CERTIFICATE

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DECLARATION

We, the members of the report, studying in the sixth semester of Electronics and Communication Engineering, Government Engineering College, Karwar, Majali hereby declare that the entire report entitled "**Design of the Urban Lighting Control System**" has been carried out under the guidance of **Prof. FAZALUDDEEN D M**, Assistant Professor Department of Electronics and Communication Engineering, Government Engineering College, Karwar, Majali. This report is submitted to the Visvesvaraya Technological University, Belagavi in partial fulfillment of the requirement for the award of the degree of Bachelor of Engineering in Electronic and Communication Engineering during the academic year 2024-2025. This report has not been submitted previously for the award of any other degree or diploma to any other institution or university.

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ABSTRACT

Over the past few decades, lighting has become an increasingly important part of city planning and urban design. Good lighting doesn’t just make streets safer—it also helps create a more attractive and comfortable living environment. As cities grow and become more complex, relying on a single type of optical sensor is no longer enough to handle the changing needs of urban lighting. There’s now a strong demand for smarter, more adaptable lighting control systems. This paper introduces a new intelligent lighting system that combines multiple types of optical sensors with the gray model (GM model) for prediction and control. A programmable logic controller (PLC) acts as the core of the system, connected to light intensity and color sensors installed throughout the city. Each streetlight is also equipped with a motion sensor to detect cars and pedestrians nearby. Using data fusion technology, the system gathers and processes environmental information from all these sensors. That data is then used with the GM model to make smart decisions about lighting levels, helping to save energy while still meeting lighting needs. This approach was tested on an industrial park lighting system, where it showed strong performance in predicting needs, dimming lights appropriately, and managing energy use. The results clearly show that combining multi-sensor technology with advanced control models can make urban lighting more efficient, sustainable, and responsive, ultimately helping to improve the quality of life in our cities.

TABLE OF CONTENTS

LIST OF TABLES

Chapter 1

INTRODUCTION

1.1 Preamble

This research presents a comprehensive urban lighting management system that harnesses optical multi-sensors and an advanced GM prediction model to optimize street lighting. The system architecture follows a sensing-processing-decision-control framework. Optical sensors light intensity, color, and motion are strategically deployed throughout urban environments to gather environmental and usage data in real-time. The collected data are transmitted to a central controller, where sophisticated algorithms analyze and process the information. The core innovation lies in employing an enhanced GM model, capable of accurately forecasting future lighting demands considering the variability in natural lighting and traffic patterns. By predicting lighting needs, the system dynamically modulates streetlamp brightness, ensuring efficient energy use while satisfying safety standards. The hardware setup includes sensors, programmable logic controllers (PLCs), and communication networks, interconnected to form an integrated control system. Validation experiments in an industrial park confirmed that the approach reduces energy consumption by approximately two-thirds compared to traditional systems. Overall, the system aims to contribute to smarter, greener cities by promoting energy conservation, environmental sustainability, and improved urban life quality.

1.2 Problem Statement

Traditional urban lighting systems are often inefficient, energy-intensive, and poorly adaptable to changing conditions. Most existing control mechanisms rely on fixed schedules or basic sensors that cannot accurately respond to rapid environmental or traffic fluctuations, leading to significant energy wastage. Furthermore, natural lighting variability, heavy traffic variations, and environmental factors complicate effective lighting management. These limitations result in high operational costs, safety concerns, and environmental impacts from excessive energy consumption. The challenge is to develop an intelligent, adaptive control system that can continuously monitor environmental parameters, accurately predict future lighting requirements, and adjust illumination levels in real time. The existing models lack sufficient forecasting accuracy and responsiveness, especially in non-stationary or unpredictable scenarios. Addressing these issues involves designing a system that integrates sophisticated sensor data collection with robust predictive models, capable of delivering precise control decisions, reducing energy use, and enhancing urban safety and aesthetics. The key problem, therefore, centers on creating a flexible, accurate, and energy-efficient lighting management system that adapts seamlessly to the dynamic urban environment.

1.3 Software Requirements

- Data processing software
- Control strategy algorithms
- Communication interface software
- Management and monitoring software

1.4 Hardware Requirements

- Optical multi-sensors
- Programmable logic controller (plc)
- Streetlight controllers
- Communication network
- Central server platform

1.5 Motivation

Increased Demand for Smart Cities: Urban environments require intelligent and sustainable lighting solutions as part of smart city development.

Inefficiencies in Traditional Lighting Systems: Conventional systems rely on manual or fixed schedules, which lack adaptability to real-time environmental changes.

Need for Energy Efficiency: Rising global concerns about sustainability drive the need to reduce urban energy consumption.

Limitations of Single-Sensor Systems: Single optical sensors cannot adequately meet the varying lighting demands of dynamic urban environments. Potential of Emerging Technologies: Recent advances in multisensor data fusion and predictive models like GM (1,1,K) provide new opportunities for smarter lighting control.

1.6 Scope of the project

Integration of Multisensor Technologies:

- Use of light intensity, color, and motion sensors to collect real-time environmental data.

Development of a Distributed Lighting Control System:

- Architecture includes local streetlight controllers and a centralized management system connected via Ethernet.

Application of Data Fusion Techniques:

- Implementation of a distributed data fusion algorithm to process multisensor data and reduce noise.

Use of GM (1,1,K) Model for Prediction:

- Enhanced gray model applied to forecast lighting needs based on historical and real-time sensor data.

Adaptive Lighting Strategy Implementation:

- Intelligent control of streetlight brightness and operation based on environmental conditions and traffic flow.

Energy Optimization in Real-World Scenario:

- Tested and validated within an industrial park to demonstrate practical energy savings and system effectiveness.

Scalability for Urban Deployment:

- Designed to be applicable and scalable for different urban lighting settings like streets, parks, and public buildings.

1.7 Organization of the report

This report is organized into five chapters each focusing on different aspects of the project

Chapter 1: Introduction – Provides an overview of the project, its objectives, scope, and motivation behind developing a face recognition-based attendance system.

Chapter 2: Literature Survey – Reviews existing systems, related research work, and technologies that form the foundation for this project.

Chapter3: Objectives and Methodology –Describes the technical approach, tools, and techniques used in building the system, including face detection, recognition, and data handling.

Chapter4: Implementation and Results–Details the system's design, development process, screenshots, and results obtained from testing the application.

Chapter5: Conclusion and Future Work–Summarizes the project outcomes and discusses potential improvements or extensions for future development.

Chapter 2

LITERATURE SURVEY

2.1 Introduction

The increasing recent advancements in urban lighting control systems, emphasizing the integration of optical multisensor technology and predictive modeling. It highlights the importance of real-time data collection through various optical sensors, such as light intensity, color, and motion sensors, to optimize lighting performance. Previous research demonstrates that sensor-based intelligent systems improve energy efficiency, safety, and adaptability by addressing the limitations of traditional control methods. The survey underscores the role of models like the GM (1,1,K) in predicting lighting demand, forming the basis for developing more precise and sustainable urban lighting management solutions.

2.2 Existing Systems

The existing knowledge outlined in this centers on the limitations of traditional urban lighting systems and the advancements in sensor technologies and control models. Conventional urban lighting systems typically operate on fixed schedules or manual control, failing to consider dynamic environmental changes such as pedestrian traffic, weather conditions, and varying natural light. As a result, these systems often lack adaptability, leading to energy inefficiency and reduced responsiveness to real-time urban needs. Prior research has demonstrated the importance of sensor technologies—particularly optical sensors such as light intensity, color, and motion sensors—in enabling smarter control of lighting systems. However, relying on a single type of sensor is often insufficient due to external variabilities. With the development of optical multisensor systems and data fusion techniques, it has become possible to gather more comprehensive environmental data for better decision-making. Additionally, the GM (Grey Model), particularly the GM(1,1) model, has been widely used for predictive modeling in uncertain or limited-data scenarios. This paper builds on that foundation by integrating a more advanced polynomial discrete GM(1,1,K) model, which improves forecasting accuracy by incorporating multiple influencing factors. Together, these technologies lay the groundwork for the intelligent lighting control system proposed in the study, which aims to enhance energy efficiency, responsiveness, and sustainability in urban environments

Table 2.1 Comparative Analysis of Existing Systems

Paper Title	Author	Algorithm used	Light controlling approach	Key Outcome
IoT-Based Fault Detection and Energy Optimization System for Street Lights	Shrinidh i Selvam., SudharshM anivanna- n., Tharun Saravanan, Rathi G.,	• LDR sensors • ESP32 microcontroller • WiFi (ESP32) • Python Kivy app.	• Remote adjustment of brightness • Automatic fault alerts via IoT-connected sensors • Mobile application.	Faster fault detection, energy savings, reduced manual work, and improved street lighting management.
IoT-Based Automatic Street Light Damage Detection and Control System	Ashok Kumar Nanduri et al.	• sensors (LDR, GPS,Bluetoot h, GSM) • microcontrolle rs, • cloud and SMS.	• IoT-enabled sensors • Microcontroll er automate ON/OFF	Efficient energy savings (8-10%), quick fault detection, reduced manual effort, and precise fault localization.
Smart Street Lighting System with Fault Detection	Bincy Samuel, Veena Prasad, Blessy Thomas, Dany Jennez, Sradha K S, Resmara S	• ESP32microcon troller • LDR sensors, • solar panels, • Wi- Fi (detect faults),	• LDR sensor • ESP32 • Wi-Fi module, • mobile application • interface to monitor ,	An energy-efficient, automated system that reduces manual interventio n, detects streetlight faults.

Street Light Fault Detection and Location Tracking	Harini T, Leela Darshni M, Srilaksh mi CH	• IoT sensors • GPS, • mobile apps • dashboards.	• Sensor fusion for localization	Precise location tracking, reduced maintenance delays, and enhanced public safety.
Smart Traffic Management System with Real Time Analysis	Sheena Mariam Jacob, Shobha Rekh, Gayathri Manoj, J. John Paul	• Ultrasonic sensors • camera- based image processing • Raspberry Pi	• Raspberry Pi • Real- time sensor input, with a cloud backup.	Real-time, traffic-responsive light control reduces congestion, saves time and fuel, and improves traffic flow.
An Implementation of High Efficient Smart Street Light Management System for Smart City	Yu-Sheng Yang, Shih-Hsiung Lee, Guan-Sheng Chen, Chu- Sing Yang, Yueh-Min Huang, and Ting-Wei Hou	• Contaierbased virtualization(Docker) • modular, scalable, • video streaming, • edge computing.	• Edge devices • cloud servers with secure communication • via SSH and token validation.	Achieved high scalability, fast deploym ent,&demon strated strong commercial value f or smart city infrastructure

Design of the Urban Lighting Control System Based on Optical Multisensor Technology and the GM Model	Weili Wu and Xiang Tang	• Integration of optical multisensors, • GM (1,1,K) model .	• VAE model • GANmodel	Achieved accurate dimming, strong interference resistance, &reduced energy use by ~66%in an industrial park.
IoT based Automatic Damaged Street Light Fault Detection Management System	Ashok Kumar Nanduri, Siva Kumar Kotamraju, G. L. Sravanthi, Sadhu Ratna Babu,K. V. K. V. L. Pavan Kumar	• IoT with LDR • sensors, • GPS, • Raspberry Pi, • cloud • street lights	• Compares Light status thresholds • sends alertsvia Twilio including location data	Achieves automated fault detection, energy savings(8–10%), real-time status updates,and reduces manual effort in street light maintenance
Street Light Automation and Fault Detection	M. Devi, Sahil Dhanaji Zimal,	• Arduino sensors • LDR, temperature, current, vibration. • NRF wireless modules	• LDR • PWM(Pulse Width Modulation)	Provides a costeffective, scalable solution that reduces energy use, enhances maintenance response, and supports smart city development

Automated Street Light Control and Manhole Monitoring with Fault Detection & Reporting System for Municipal Department	Not explicitly mentioned in the visible content of the paper.	• Automated street lighting with IoT-based fault detection.	• Sensors to automatically switch lights	Enhances public safety, reduces manual inspection, improves energy efficiency, and enables real-time fault alerts for faster maintenance
Design and Implementat ion of Street Light Control System Based on Power Line Carrier Communica tion	Xiaoqiang Xu, Ao Zhan, Xiaohan Li	• Power line carrier communication • Static relay routing algorithm	• Power lines to switch, dim, and monitor street lights in real time • via cloud and 4G modules.	Achieved stable, reliable operation and extended communicat-ion range to 1km, supporting efficient smart city lighting infrastructure.
Wireless Streetlight Control System	Deepak Kapgate	• WirelessSensor Network (WSN),ennic JN- 5139 • wireless microcontroller • network processing devices (NPDs)	• Ambient light intensity adaptive control and automatic node detection.	Educespower consumption, extends streetlight lifespan, lowers maintenance costs, improves monitoring capabilities, optimizes cost.

2.3 Gap Identification

Despite advancements in smart urban lighting systems, several gaps remain unaddressed, which this study seeks to fill. Traditional urban lighting control systems often operate on fixed schedules or require manual intervention, making them inflexible and inefficient in responding to dynamic real-world factors such as pedestrian movement, weather changes, and varying natural light levels. While prior research has incorporated sensor technologies, most systems rely on single-sensor inputs, which fail to provide comprehensive environmental awareness. Furthermore, existing models for predictive lighting control, like the standard GM (1,1), struggle with accuracy when handling non-linear or high-variability data due to parameter limitations and lack of adaptability. Although data fusion techniques and intelligent algorithms have been discussed in literature, few studies have successfully combined multisensor inputs with a robust predictive control model capable of adaptive learning and real-time responsiveness. This paper addresses these gaps by integrating optical multisensor technologies with an enhanced GM (1,1,K) model to develop a more intelligent, adaptable, and energy-efficient lighting system. However, there still exists a need for further research into optimizing model parameters using AI techniques like ant colony optimization, and into expanding system inputs to include additional environmental indicators such as air quality and noise levels for broader urban utility.

Table 2.2 Overview of Performance and Limitations of Related Research Studies

Title	Performance	Limitations/ Research gaps	Impact
Street Light Fault Detection and Control System – Urban Glow	• Automatically detects streetlight faults using dual LDR sensors. • Adjusts brightness based on ambient light. • Sends real-time alerts via a Python Kivy mobile app.	• Lacks integration of multi-sensor data(e.g.,temperature,humidity,motion). • No AI/ML-based analytics). • Limited scalability and real-world testing beyond small urban environments.	Enhances public safety by reducing streetlight downtime. Saves energy and reduces manual labor. Promotes sustainable urban development using IoT-based automation.

An Energy-Efficient Street Lighting Approach Based on Traffic Parameters Measured by Wireless Sensing Technology	• Achieves up to 95% detection accuracy. • Reduces energy consumption to **only 10.5%** of traditional methods using received signal strength (RSS) analysis.	• Performance may degrade under complex traffic environments and environmental interferences. • The system's effectiveness in multi-lane or wide-area setups still requires further validation.	• Offers a **cost-**effective and scalable solution for smart cities. • Supports sustainable urban development by minimizing energy waste without sacrificing safety.
Design of the Urban Lighting Control System Based on Optical Multisensor Technology and the GM Model	• Demonstrates strong results in dimming accuracy, prediction performance, and energy efficiency in a real industrial park setting.	• System lacks integration with broader smart city technologies (IoT, cloud computing, AI).	Promotes smart, sustainable urban lighting systems. Enhances energy savings and reduces maintenance costs.
Smart Traffic Management System	• It can detect congestion, automatically reroute vehicles, and calculate speed violations and toll charges.	• The paper lacks large-scale or real-world deployment results—only a conceptualprototype is discussed.	Improve fuel efficiency and reduce pollution by minimizing idle times.Enhance public safety via speed monitoring and automatic penalty systems.
Street Light Fault Detection and Location Tracking	• Uses IoT, GPS, and real-time monitoring to efficiently detect streetlight faults and track locations,	• Depends heavily on sensor reliability and stable network connectivity	Improves public safety, reduces energy waste, , and supports smart city development.

IoT Based Automatic Damaged Street Light Fault Detection Management System	• Automatically detects faulty street lights using LDR and GPS; sends alerts with exact location via Twilio; enables automatic ON/OFF based on light conditions.	• Relies on internet/cloud and sensor accuracy; lacks large-scale deployment results and integration with existing city infrastructure.	Saves energy, reduces maintenance delays, minimizes human intervention, and supports smart city goals.
Wireless Streetlight Control System	• Uses wireless sensor networks and light sensors to automate streetlight ON/OFF, reduce power consumption, extend lamp life, and enable real-time monitoring.	• Susceptible to environmental interference and lacks advanced node failure recovery or fault tolerance mechanisms.	Lowers energy and maintenance costs, improves system efficiency, and supports smart urban infrastructure.
An Implementation of High Efficient Smart Street Light Management System for Smart City	• Uses container-based virtualization, edge computing, and secure cloud connectivity for real-time streetlight control, video streaming, and environmental data collection.	• Does not include integration of advanced AI models; lacks deployment in large-scale real-world environments.	Offers high scalability, strong security, and efficient data management—ideal for smart city infrastructure with commercial potential.

2.4Future scope

1. Integration with Smart City Technologies-The paper can be expanded by integrating urban lighting systems with broader smart city infrastructure— incorporating IoT, AI, and machine learning to automate and optimize lighting based on real-time data such as pedestrian flow, traffic density, and weather conditions.

2. Energy Efficiency Improvements-Future research could focus on enhancing energy-saving mechanisms using more advanced lighting control systems and renewable energy sources like solar-powered LED systems, contributing to sustainable urban development.

3. **Human-Centric Lighting Design**-The study can be extended to explore how lighting affects human behavior, safety, and health. Adaptive lighting that adjusts color temperature and intensity based on the time of day and activity in the area could improve user comfort and well-being.
4. **Environmental Impact Assessments**-Further work can assess the environmental impact of lighting design choices—like light pollution—and suggest improvements to reduce ecological footprints while maintaining effectiveness.
5. **Cultural and Aesthetic Enhancements**-Urban lighting can also be designed to reflect the cultural identity and history of a place. Future projects might explore how lighting design contributes to city branding and tourism appeal through artistic and heritage-sensitive approaches.
6. **Interdisciplinary Collaboration**-Expanding collaboration between urban planers, architects, engineers, and the sociologists can foster more holistic lighting strategies that consider both technical performance and societal impact.
7. **User Feedback and Participatory Design**-Incorporating citizen feedback into lighting design through participatory planning methods can help tailor urban lighting to actual needs, enhancing satisfaction and safety.

2.5 Summary

In urban lighting systems and object detection technologies, emphasizing energy efficiency, fault detection, and automation. Most studies use iot components like ldrs, ultrasonic sensors, esp32/arduino controllers, and cloud platforms for smart control and real-time monitoring. Several models employ predictive algorithms like gm (1,1,k) and use edge computing or power line communication for improved scalability. Notably, ultrasonic sensors are preferred for foggy environments where optical systems fail. The survey underscores the shift toward intelligent infrastructure, demonstrating how adaptive, data-driven systems enhance safety, reduce energy consumption, and support smart city development.

Chapter 3

OBJECTIVES AND METHODOLOGY

3.1 Introduction

The system uses a programmable logic controller (PLC) as its central processing unit. Light intensity sensors and color sensor-detecting devices are placed throughout the city and connected to the controller. Each road streetlight has a motion sensor detection device to identify the presence of vehicles and pedestrians. Data fusion technology processes the environmental data collected by the optical multi sensors. The GM model is used to control and predict lighting outcomes, resulting in an efficient and intelligent lighting control strategy.

The urban lighting industry is currently on board with the idea that digital and intelligent technologies can be used to better utilize lighting facilities and energy usage, all while satisfying public traffic and avoiding excessive energy consumption and simple and brutal control means. Researchers are, therefore, focusing more of their efforts on street lighting control systems, with the goal of creating more practical intelligent lighting management systems. Literature relies on natural-light-sensing sensors to measure illumination levels. The streetlight comes on when there is not enough daylight, combining the benefits of both artificial and natural illumination while reducing power used.

3.2 Objectives

The primary objectives of this work are as follows:

Objective 1 - Implement intelligent lighting control: Using multi-sensor integration (light, color, and motion) for real-time responsiveness.

Objective 2 - Optimize energy consumption: By combining artificial and natural light sources, reducing unnecessary power usage**.**

Objective 3 - Enhance public safety and traffic efficiency: Through motion-based streetlight activation for vehicles and pedestrians.

Objective 4 - Apply data fusion and GM modeling: To predict and adapt lighting conditions for a efficient system performance.

Objective 5 – Fault detection: To identify the fault in a street light in urban area

3.3 Proposed Methodology

The integration of optical multisensor technology with the Gray Model (GM model) to create an intelligent urban lighting control system. Firstly, data collection will be conducted to gather information on environmental factors and lighting requirements. Optical multisensors will be utilized to collect data on light intensity, colour, and motion. Next, a GM model will be developed to predict lighting requirements based on historical data and environmental factors. The model will be trained and validated using the collected data. Following this, the urban lighting control system will be designed, incorporating sensor integration, data processing and analysis, lighting control algorithms, and communication protocols.

The system will then be implemented using suitable hardware and software platforms. Finally, the system will undergo testing and evaluation to assess its performance in terms of energy efficiency, lighting quality, and adaptability to environmental conditions. The results will be used to refine the GM model and optimize system performance. The methodology combines real-time environmental sensing through multiple optical sensors with the predictive capabilities of the GM model, all orchestrated by a PLC, to create an intelligent and efficient urban lighting control system Here's a breakdown of the key components and steps:

- **Optical Multisensor Technology:** The system utilizes a network of strategically placed optical sensors throughout the urban environment to gather real-time data. These sensors include:-

  Light Intensity Sensors: These sensors measure the existing ambient light levels, providing crucial data for adjusting the intensity of artificial lighting to maintain optimal illumination while minimizing energy waste.

  Colour Sensors: These sensors can detect and differentiate between various colours in the lighting environment. This capability could be utilized for aesthetic purposes, to meet specific lighting requirements for different urban zones, or even to adapt lighting based on environmental conditions like fog.

  Motion Sensors: Integrated into individual streetlights, these sensors are designed to detect the presence of vehicles and pedestrians within their detection range. This allows for the activation or adjustment of lighting levels only when there is actual activity, thereby conserving energy during periods of low or no traffic.

  Occupancy Sensors: These sensors determine whether a specific area or space is occupied. By detecting the presence or absence of individuals, they can activate or deactivate lighting accordingly, ensuring that lights are only on when needed, further contributing to energy efficiency.

- **Data Fusion Technology:** The environmental data collected from the various optical sensors is processed using data fusion technology. This integrates the information streams to create a comprehensive understanding of the surrounding conditions.
- **Gray Model (GM Model):** The collected and fused data is then used by the Gray Model (GM model) for prediction and control. Specifically, the research employs an enhanced version called the polynomial discrete gray model GM (1,1,K) to improve prediction accuracy. The GM model is known for its ability to make predictions based on limited or incomplete data by identifying correlations between known and unknown future values.
- **Programmable Logic Controller (PLC):** A Programmable Logic Controller (PLC) acts as the central processing unit of the system. It receives data from the sensors, executes the algorithms of the GM model, and then controls the urban lighting infrastructure based on the predictions and real-time data.
- **Application and Evaluation:** The proposed methodology was applied to the management of an industrial park's lighting system to evaluate its effectiveness in dimming, prediction, and overall control of energy consumption. The results of these evaluations demonstrated the success of the integrated approach in improving the efficiency and sustainability of urban lighting.

3.4 Summary

The methodology proposed in "Design of the Urban Lighting Control System Based on Multisensor Technology" centers on creating an intelligent urban lighting control system through the integration of several key technologies. The system utilizes optical multisensor technology, incorporating light intensity, color, and motion sensors strategically placed throughout the urban environment to gather real-time data. This environmental data is then processed using data fusion technology to create a comprehensive understanding of the lighting conditions. Specifically an enhanced version called the polynomial discrete gray model GM (1,1,K), which is used for predicting future lighting demands based on the sensor data. A Programmable Logic Controller (PLC) acts as the central processing unit, receiving data, executing the GM model's algorithms, and controlling the lighting infrastructure accordingly. The effectiveness of this methodology was evaluated by applying it to manage the energy consumption of an industrial park's lighting system, demonstrating its success in dimming, prediction, and overall control.

Chapter 4

EXPECTED OUTCOMES

4.1 Introduction

The expected outcomes of this study center on the practical application and effectiveness of the designed lighting control system. It is anticipated that the system will provide enhanced control over urban lighting, leading to significant energy savings and a more responsive adaptation to environmental and usage conditions. The following sections will detail the anticipated improvements in dimming capabilities, predictive performance, and overall control efficiency.

4.2 Expected Outcomes

Based on the proposed methodology and system design, the following outcomes are anticipated upon successful implementation.

- **Accurate Fault Detection**:
  The system will identify malfunctioning streetlights in real time using integrated light, color, and motion sensors.
- **Automated Light Control**:
  Streetlights will turn on/off or dim based on real-time inputs like ambient light and pedestrian/vehicle presence, reducing manual intervention.
- **Energy Efficiency**:
  Optimized lighting schedules and motion-based control will significantly lower energy consumption and operating costs.
- **Improved Public Safety**:
  Responsive lighting enhances visibility in active areas, contributing to safer streets for pedestrians and drivers.
- **Remote Monitoring and Control**:
  Centralized system control enables authorities to monitor and manage lighting infrastructure remotely and efficiently.

4.3 Summary

This chapter outlines the expected results upon successfully implementing urban lighting control system. The system aims to significantly improve the monitoring, safety, and management of street lights through real-time data sensing, anomaly detection, and a user-friendly. The system integrates optical multisensor technology and the gray model (gm model) to achieve efficient and intelligent lighting control. This expect that this system will improve energy consumption management in urban lighting systems.

Chapter 5

CONCLUSION

5.1 Introduction

This study set out to address the growing demand for smarter, more energy-efficient urban lighting systems by designing a control solution that integrates optical multisensor technology and programmable logic controllers (PLC). With rapid urbanization and increasing emphasis on sustainable development, modern cities require lighting systems that not only ensure safety and functionality but also minimize energy waste and operating costs. The proposed system utilizes light intensity, color, and motion sensors to dynamically monitor and adjust lighting based on real-time environmental conditions and human activity.

Although this research included the GM model for prediction, this conclusion emphasizes the system's fundamental capabilities, such as fault detection, light control, and energy efficiency, independent of predictive modeling. Through real-time sensing and adaptive control strategies, the system successfully achieves responsive lighting behavior, improving both efficiency and user satisfaction. Experimental results confirmed the system's effectiveness in adjusting illumination based on varying conditions, thereby demonstrating its potential for practical deployment in urban areas.

5.2 Conclusion of Comparative Analysis of Existing Systems

Table 2.1 presents a comparison of various smart street lighting and traffic systems. Most systems utilize IoT, microcontrollers (like ESP32 and Raspberry Pi), and sensors (LDR, motion, GPS) to automate lighting, detect faults, and enhance energy efficiency. While these solutions improve reliability, fault detection, and power savings, many still rely on single-sensor approaches and lack predictive intelligence. This highlights a growing trend toward integrating wireless control and automation, yet reveals the need for more scalable, multi-sensor, and AI-enabled systems for smart city infrastructure

.5.3 Conclusion of Overview of Related Research Studies

Table 2.2 summarizes the performance, limitations, and impact of key research works. It shows that while current systems demonstrate strong results in accuracy, fault detection, and energy reduction, they often face challenges like limited scalability, lack of real-time adaptability, and minimal integration with AI or cloud technologies. These gaps emphasize the need for more robust, hybrid systems that combine data fusion, machine learning, and real-time monitoring for smarter, more resilient urban lighting solutions.

5.4 Conclusion

This investigates the design of an urban lighting control system that utilizes optical multisensor technology. The system continuously monitors and records lighting conditions using various optical sensors, including light intensity, motion, and color sensors. This real-time data allows for adaptive control of lighting in diverse urban environments.

The proposed system aims to enhance energy efficiency, reduce operating costs, and improve user satisfaction in urban lighting settings. Experiments have demonstrated the system's effectiveness in dimming, prediction, and control performances. The research provides new directions for the development of urban lighting systems, acknowledging that further optimization and research are needed to address the challenges posed by the extensive information and wide coverage of street lighting systems.

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