WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Adaptive LED Lighting System for Glare Mitigation and Improved Road Visibility

Swati Masti[1], Suraj Mullur [2], Prof. Sneha A.J.[3], Suprita Shirahatti [4], Shridhar Sankonatti [5]

[1] Department of Electronics and Communication Engineering Jain College of Engineering and Research Belagavi, India
[2] Department of Electronics and Communication Engineering Jain College of Engineering and Research Belagavi, India
[3] Department of Electronics and Communication Engineering Jain College of Engineering and Research Belagavi, India
[4] *Department of Electronics and Communication Engineering Jain College of Engineering and Research* Belagavi, India
[5] *Department of Electronics and Communication Engineering Jain College of Engineering and Research* Belagavi, India

ABSTRACT—

This paper presents an adaptive matrix headlamp system designed to improve nighttime driving safety by reducing glare from oncoming vehicles. The system uses sensors and a camera to detect vehicles and identify their position relative to the headlamp. Based on the detected vehicle region, individual LED segments are controlled to reduce light intensity in the corresponding area while maintaining illumination in other regions. An Arduino Uno is used to process the sensor inputs and control the LED matrix. The proposed system provides selective beam control, improves visibility, and reduces glare for oncoming drivers. The system offers a low cost approach for implementing adaptive lighting in vehicles and can contribute to safer nighttime driving.

***Index Terms*—Adaptive headlamp, matrix LED, vehicle detection, glare reduction, nighttime driving, intelligent lighting**

I. INTRODUCTION

Nighttime driving can be challenging due to reduced visibility and glare caused by vehicle headlights. Conventional headlamps provide a fixed beam pattern, which may illuminate oncoming vehicles directly and cause discomfort or temporary vision impairment to other drivers. An adaptive headlamp system can overcome this limitation by controlling the direction and intensity of light according to the surrounding traffic conditions.

This paper presents an Adaptive Matrix Headlamp System that detects vehicles and selectively controls individual LED segments. The system uses a camera and sensors to identify the position of vehicles and reduce the light intensity in the corresponding region. An Arduino Uno processes the sensor inputs and controls the LED matrix. This allows the remaining areas of the road to remain illuminated while reducing glare toward other vehicles.

The proposed system aims to improve nighttime visibility, reduce glare, and enhance driving safety using a low cost and practical approach. The system can be further developed for advanced automotive lighting applications.

II. EASE OF USE

The proposed adaptive matrix headlamp system is designed to operate automatically with minimal driver intervention. The system detects vehicles using a camera and sensors and controls the corresponding LED segments according to the detected vehicle position. This helps reduce glare for oncoming vehicles while maintaining adequate illumination of the surrounding road area [1].

The system uses an Arduino Uno for processing sensor inputs and controlling the LED matrix. The use of easily available and low cost components makes the proposed system simple to implement and suitable for prototype development. Similar camera based vehicle detection methods have been studied for adaptive driving beam systems [4].

A. System Specifications

The proposed adaptive matrix headlamp system is developed using an Arduino Uno, camera module, ultrasonic sensors, IR sensors, LED matrix, LED driver unit, and power supply. The camera and sensors are used to detect vehicles and determine their position, while the Arduino Uno processes the input signals and controls the corresponding LED segments.

The system is designed to reduce glare by selectively controlling the LED segments facing the detected vehicle. The remaining LED segments continue to provide illumination for the surrounding road area. The system specifications are selected to achieve a simple, low cost, and practical prototype for adaptive vehicle lighting.

III. SYSTEM PREPARATION

The proposed adaptive matrix headlamp system is designed by integrating a camera module, ultrasonic sensors, IR sensors, Arduino Uno, LED matrix, LED driver unit, and power supply. The hardware and software components are configured to work together for detecting vehicles and controlling the headlamp segments.

The camera and sensors provide information about the surrounding vehicles, while the Arduino Uno processes the received inputs. Based on the detected vehicle position, the corresponding LED segments are controlled to reduce glare. The remaining LED segments continue to illuminate the road, providing improved visibility during nighttime driving [1].

A. Abbreviations and Acronyms

The following abbreviations are used in this paper: LED stands for Light Emitting Diode, IR stands for Infrared, and PWM stands for Pulse Width Modulation. Arduino Uno is used as the main microcontroller for processing sensor inputs and controlling the LED matrix. The term Adaptive Matrix Headlamp System is used to describe the proposed intelligent headlamp system.

B. Units

- The International System of Units (SI) is used throughout this paper. Distance is expressed in centimeters (cm), voltage in volts (V), and current in amperes (A).
- Sensor measurements such as vehicle distance are represented using standard SI units to maintain consistency throughout the system.
- Mathematical equations use consistent units for all physical quantities. For example, the distance measured by the ultrasonic sensor is expressed in centimeters.
- Decimal values are written with a zero before the dec-imal point, such as 0.25, to maintain IEEE formatting conventions.

C. Equations

The distance of a detected vehicle is calculated using the time taken by the ultrasonic signal to travel to the object and return to the sensor. The distance is given by

$$d = \frac{vt}{2} \tag{1}$$

where d is the distance between the sensor and the detected vehicle, v is the speed of sound in air, and t is the measured time interval.

The electrical power consumed by the LED matrix can be calculated using

$$P = V I \tag{2}$$

where P is the electrical power, V is the applied voltage, and I is the current consumed by the LED matrix.

IV. PROPOSED SYSTEM

The proposed adaptive matrix headlamp system is designed to improve nighttime driving safety by detecting vehicles and selectively controlling the headlamp beam. The system consists of a camera module, ultrasonic sensors, IR sensors, Arduino Uno, LED matrix, LED driver unit, and power supply. The camera and sensors detect the presence and position of vehicles in front of the system. The Arduino Uno processes the sensor information and controls the corresponding LED segments. When a vehicle is detected in a particular region, the associated LED segments are dimmed or switched off to reduce glare, while the remaining segments continue to
illuminate the road.

This selective control of the LED matrix provides better visibility for the driver while reducing glare for oncoming vehicles. The proposed system uses low cost components and provides a practical approach for implementing adaptive vehicle lighting.

A. Some Common Mistakes

During the development of the adaptive matrix headlamp system, care must be taken to ensure correct sensor connections, proper power supply, and accurate vehicle detection. Incorrect sensor readings may result in improper LED segment control and may affect the performance of the system.

The camera and sensors should be positioned correctly to obtain reliable vehicle detection. The threshold values used for vehicle detection should also be selected appropriately to avoid unnecessary switching of the LED segments.

The Arduino Uno, LED driver, and LED matrix should be connected according to their required voltage and current ratings. Proper grounding and power connections are necessary for stable system operation. The LED segments should be controlled according to the detected vehicle position so that glare is reduced without significantly affecting the illumination of the road.

B. Authors and Affiliations

The authors of this paper are Swati Masti, Suprita Shira-hatti, Suraj Mullur, and Shridhar Sankonatti. All authors are affiliated with the Department of

Electronics and Communica-tion Engineering, Jain College of Engineering and Research, Visvesvaraya Technological University, Belagavi, India.

C. System Organization

The paper is organized into several sections to describe the development and operation of the proposed adaptive matrix headlamp system. The introduction presents the need for adaptive headlamp technology and the objectives of the proposed system. The literature review discusses existing vehicle detection and adaptive lighting approaches.

The proposed system section describes the hardware components, system architecture, vehicle detection process, and LED matrix control. The results and discussion section presents the observed performance of the system. Finally, the conclusion summarizes the proposed approach and discusses its potential for improving nighttime driving safety.

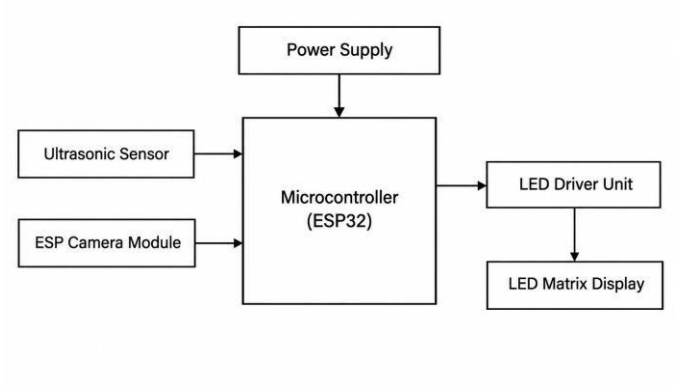


Fig. 1. Block diagram of the proposed adaptive matrix headlamp system.

V. IMPLEMENTATION

The proposed adaptive matrix headlamp system is implemented by integrating the ESP32, ESP32 camera module, ultrasonic sensor, servo motor, LED matrix headlamp, LED drive unit, and power supply. The ESP32 acts as the main controller and processes the inputs received from the sensors and camera module.

The ESP32 camera module is used to detect the presence and position of vehicles in front of the headlamp. The ultra-sonic sensor is used to measure the distance of the detected vehicle. Based on the detected vehicle position and distance, the ESP32 determines the corresponding LED segments that need to be dimmed or switched off.

The LED matrix headlamp is divided into multiple sections to provide selective illumination. When an oncoming vehicle is detected, the corresponding LED section is controlled through the LED drive unit to reduce glare toward the vehicle. The remaining LED sections continue to illuminate the road, thereby maintaining adequate visibility.

The servo motor is used to provide the required mechanical movement in the implemented prototype. The complete system is powered using the specified power supply, and the control program is developed and uploaded to the ESP32 using the Arduino IDE.

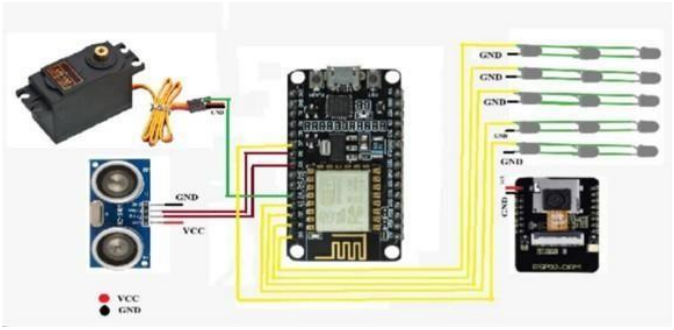
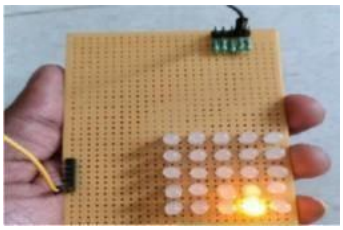


Fig. 2. Circuit Diagram of LED Matrix Headlamp System

Fig. 3. Led Matrix



VI. RESULTS AND DISCUSSION

The proposed adaptive matrix headlamp system was successfully implemented and tested. The system detected the vehicle and controlled the corresponding LED segments to reduce glare while maintaining illumination in the remaining regions. The experimental observation demonstrates that the proposed system can selectively control the LED matrix based on the detected vehicle condition, thereby reducing glare and improving nighttime visibility.

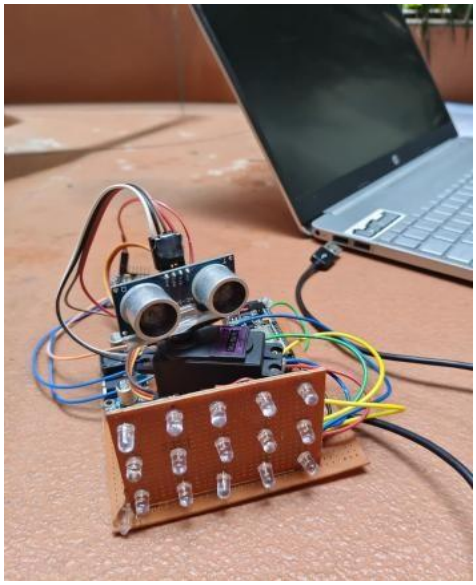


Fig. 4. Experimental result of the adaptive matrix headlamp system.

VII. CONCLUSION AND FUTURE SCOPE

A. Conclusion

The proposed adaptive matrix headlamp system aims to improve nighttime driving safety by reducing glare caused by oncoming vehicles. The system integrates an ESP32, camera module, ultrasonic sensor, servo motor, and LED matrix headlamp to support vehicle detection and selective light control. Based on the detected vehicle position, the corresponding LED segments can be controlled while the remaining segments provide illumination to the surrounding area. This approach offers a practical and low-cost solution for adaptive automotive lighting.

B. Future Scope

The proposed system can be improved by implementing advanced image processing and object detection algorithms to identify vehicles more accurately under different lighting and weather conditions. The LED matrix can be enhanced with a greater number of individually controlled segments for more precise illumination. Future development may also include testing at different vehicle speeds and distances, evaluating glare reduction quantitatively, and optimizing power consumption. These improvements could make the system more reliable and suitable for real-world automotive applications.

ACKNOWLEDGMENT

The authors, Swati Masti, Suprita Shirahatti, Suraj Mullur, and Shridhar Sankonatti, would like to express their sincere gratitude to Jain College of Engineering and Research, Belagavi, affiliated with Visvesvaraya Technological University, for providing the necessary facilities and support to carry out this project. The authors also thank the faculty members of the Department of Electronics and Communication Engineering for their valuable guidance and encouragement throughout the development of the proposed adaptive matrix headlamp system.

REFERENCES

[1] S. Singh, U. Sharma, I. Kasana, and S. Sadhu, "Design and implementation of an adaptive headlight system model for enhanced night-time driving safety," *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, vol. 238, no. 13, 2023.

[2] B. Y. Lee, J. S. Lee, and M. S. Park, "Adaptive driving beam system design and implementation using image processing," *Sensors*, vol. 19, no. 9, 2023.

[3] M. Waldner, N. Mu¨ller, and T. Bertram, "Energy efficient illumination by matrix headlamps for night time automated object detection," *International Journal of Electrical and Computer Engineering Research (IJECER)*, vol. 2, no. 3, 2022.

[4] R. K. Jurgen, "Automotive lighting and human vision," *SAE International*, 2020.

[5] S. Li and L. Zhao, "A low-cost and fast vehicle detection algorithm with a monocular camera for adaptive driving beam systems," *IEEE Access*, vol. 9, pp. 26147–26155, 2021, doi: 10.1109/ACCESS.2021.3057862.

[6] S. Singh, U. Sharma, I. Kasana, and S. Sadhu, "Adaptive headlamps in automobile: A review on the models, detection techniques, and mathematical models," *IEEE Access*, vol. 9, 2021, doi: 10.1109/ACCESS.2021.3088036.

[7] S. R. K. ... "Design and integration of lane departure warning, adaptive headlight and wiper system for automobile safety," in *Proc. 2019 4th Int. Conf. Recent Trends in Electronics, Information, Communication & Technology (RTEICT)*, 2019, doi: 10.1109/RTEICT46194.2019.9016731.

[8] "Automotive lighting systems based on luminance/intensity grids: A proposal based on real-time monitoring and control for safer driving," *Computers, Materials & Continua*, vol. 66, no. 3, pp. 2373–2383, 2021, doi: 10.32604/cmc.2021.013151.

[9] "Modeling and implementation of an adaptive vehicle light management system," in *Proc. 2021 Zooming Innovation in Consumer Technologies Conference (ZINC)*, 2021, doi: 10.1109/ZINC52049.2021.9499252.

[10] "Intelligent headlight control using learning-based approaches," in *Proc. 2011 IEEE Intelligent Vehicles Symposium (IV)*, 2011, doi: 10.1109/IVS.2011.5940541.