IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 2, January 2026
Impact Factor: 7.67

Smart Embedded Night Vision System for Pedestrian Detection

Kalyani Pawar[1], Akshara Borase[2], Nisha More[3], Darshan Pahade[4] ,S.S.Aher[5]
Students, Department of Computer Technology [1,2,3,4]
Professor, Department of Computer Technology [5]
SNJB's Shri Hiralal Hastimal Jain Brothers Polytechnic Chandwad, Nashik, Maharashtra, India

Abstract: *Night-time driving is risky because humans cannot see clearly in the dark, but unfortunately pedestrians and animals do not glow in the headlights on time. As a result, road accidents increase, and drivers realize the problem only after it is too late. To reduce this issue, this project introduces an Embedded Night Vision System for Pedestrian Detection using an ESP32 microcontroller.The system is mounted on a small car prototype that acts smarter than some real drivers. It uses PIR sensors to detect humans and animals by sensing the heat they naturally emit—because living beings cannot hide their body temperature. Once motion is detected, the ESP32 quickly reacts by alerting the driver and controlling the vehicle movement before panic braking is required.The car can be controlled wirelessly using Bluetooth through a mobile application, while an L298N motor driver ensures smooth movement of the DC motors.Overall, this project proves that with a little intelligence, a car can "see" better at night and help avoid accidents. Future upgrades may include cameras, AI, and IoT—because even cars deserve smarter vision.*

Keywords: Embedded systems for vehicle safety, Night-time pedestrian and animal detection, PIR sensor-based motion detection, ESP32 microcontroller applications, Bluetooth-controlled prototype vehicles, DC motor and L298N driver integration, Intelligent sensing for low-light driving

I. INTRODUCTION

Agriculture is With the rapid increase in vehicles and urban population, road safety has become a major concern, especially during night-time. Reduced visibility, poor lighting, and unexpected movement of pedestrians or animals often lead to serious accidents. Traditional vehicle headlights provide limited coverage, making it difficult for drivers to detect obstacles in time.

To address these challenges, this project presents an Embedded Night Vision System for Pedestrian Detection, designed to improve night-time road safety using intelligent sensing technology. The system uses PIR sensors to detect humans and animals based on body heat, offering a cost-effective and energy-efficient alternative to camera-based systems that struggle in low-light conditions.The system is powered by an ESP32 microcontroller, chosen for its high processing capability, low power consumption, and built-in Bluetooth support. The prototype is implemented on a car model, where DC motors are controlled using an L298N motor driver. Bluetooth connectivity allows manual operation of the vehicle through a smartphone, making the system easy to test and demonstrate.By combining embedded sensing, smart control, and real-time detection, this project aims to enhance night-time driving safety, reduce accidents, and showcase how intelligent systems can be applied in automotive safety applications.

II. LITERATURE REVIEW

In 2015, Kim and his team introduced an embedded night-vision system using infrared (IR) cameras to detect pedestrians. Their system used IR LEDs and photodiodes to sense humans and animals at night, showing that IR-based detection could improve night-time safety by identifying obstacles up to 100 meters, even in very low-light conditions.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 2, January 2026
Impact Factor: 7.67

A few years later, in 2017, Zhang and colleagues developed a thermal camera-based system for pedestrian detection. They demonstrated that thermal sensors could capture heat signatures from humans, animals, and vehicles, making it possible to detect objects even in complete darkness. They also used image processing algorithms like HOG (Histogram of Oriented Gradients) and SVM (Support Vector Machine) to improve accuracy.

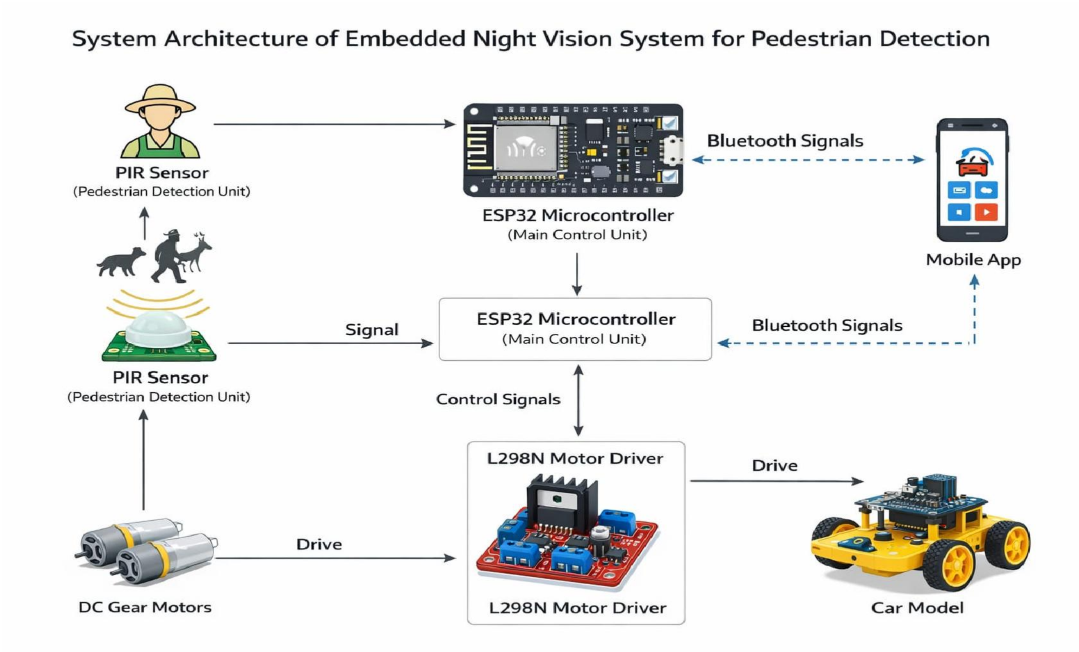
In 2018, Sharma and his team explored microcontroller-based embedded systems for vehicle safety. By integrating IR sensors with platforms like Arduino and ESP32, their system could alert drivers about nearby pedestrians at night. This work highlighted that microcontroller-based solutions are not only reliable but also low-cost and energy-efficient compared to traditional camera-based systems.

In 2019, Li and his team proposed a more advanced system that combined thermal imaging with real-time deep learning algorithms for pedestrian detection. Their research showed that embedded night-vision systems could effectively identify pedestrians in low-light or nighttime conditions, enhancing vehicle safety and reducing accidents.

More recently, in 2021, Patel and colleagues focused on creating affordable night-vision solutions for urban vehicles. They combined PIR sensors with an ESP32 microcontroller and Bluetooth connectivity to build a prototype car. Their study emphasized that using simple sensors and embedded processing units could achieve reliable pedestrian detection while keeping the system easy to implement and cost-effective.

III. PROBLEM STATEMENTS

Night-time road accidents are a major safety concern, often caused by poor visibility and the delayed detection of pedestrians or animals. Conventional vehicle headlights provide limited illumination and are often insufficient to alert drivers in time. While advanced night-vision systems exist in modern vehicles, they are usually expensive and not accessible to all users.This creates a need for a cost-effective, reliable, and easy-to-implement embedded system that can detect pedestrians and animals in low-light or nighttime conditions. Such a system would assist drivers in taking timely action, ultimately reducing accidents and improving road safety for everyone.



DOI: 10.48175/IJARSCT-30886

IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429

Volume 6, Issue 2, January 2026

Impact Factor: 7.67

V. DESIGN OF THE PROJECT

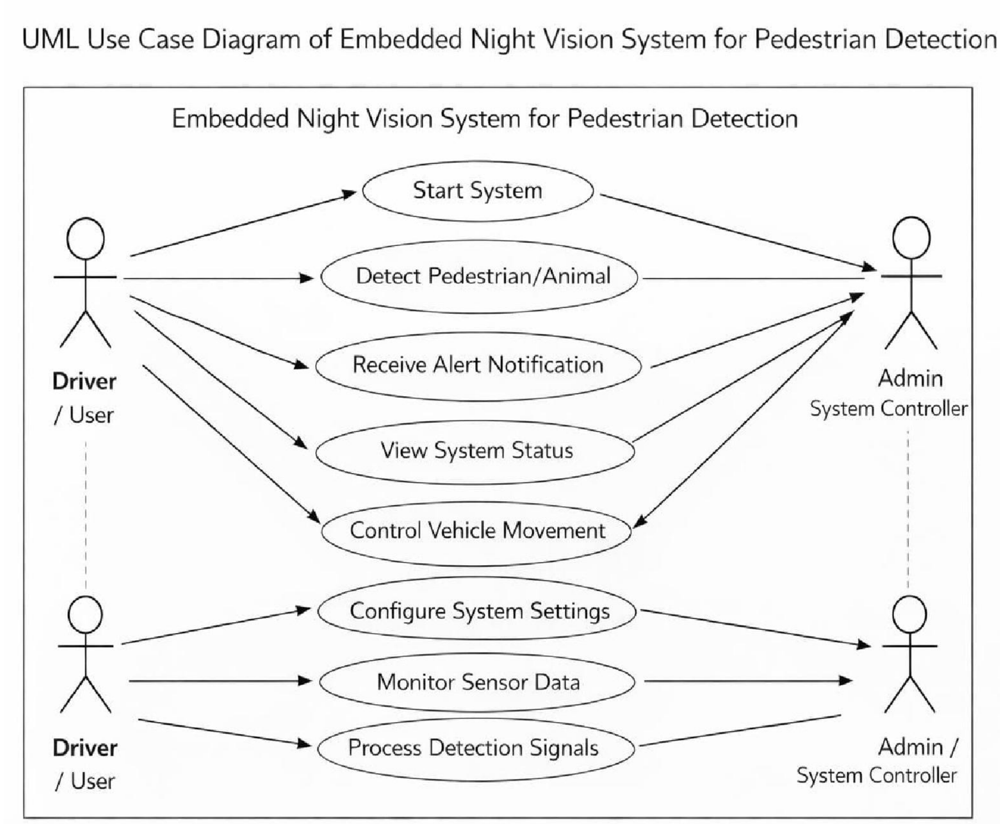


Figure: UML Case Diagram

VI. DESIGN AND IMPLEMENTATION CONSTRAINTS

Our Embedded Night Vision System for Pedestrian Detection is made up of three main parts: the car prototype, the ESP32 microcontroller, and the sensors. The system is designed to be simple, reliable, and affordable, helping to detect pedestrians or animals at night to improve road safety.

6.1 External Interface Requirements

User Interfaces - The system comes with a mobile app that allows the user to control the car via Bluetooth. It also has a small 16x2 LCD display that shows alerts whenever a pedestrian or animal is detected. The controls are easy to use, so even someone with minimal technical knowledge can operate the system..

Hardware Interfaces - The system doesn't need any special hardware. All you need is the ESP32 microcontroller, PIR sensors, L298N motor driver, and DC motors.PIR sensors detect the heat emitted by humans or animals to identify motion. You can operate the system using a standard smartphone or computer that supports Bluetooth..

Software Interfaces The ESP32 is programmed using Arduino IDE in C/C++.It handles all sensor inputs and controls the motors. Communication between the car and the mobile app is done using Bluetooth, which is secure and fast.In the future, AI-based image processing or IoT features can be added to make the system smarter..

Communications Interfaces: The car and the mobile app talk to each other through Bluetooth. All commands and alerts are sent securely using standard communication protocols.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 2, January 2026
Impact Factor: 7.67

6.2 Other Non Functional Requirements

- Performance Requirements - The system reacts in real-time to any pedestrian or animal entering its path. The ESP32 ensures smooth processing, so the car can stop or alert the user immediately. Even in complete darkness, the system works reliably.
- Safety Requirements - The electronic circuits are designed to prevent any electrical hazards. Emergency stop functionality ensures the car can be stopped quickly if needed. The system is tested regularly to make sure it works without unexpected failures.
- Security Requirements - Only paired mobile devices can control the car, so no unauthorized user can interfere. Bluetooth communication is secure to protect against accidental misuse.
- Software Quality Attributes:
- Availability - The system is ready to use whenever it's powered on.
- Reliability - The sensors and motor controls are accurate, so the system can be trusted.

6.3 Software Hardware Requirements

- Programming Languages: Programming: Arduino IDE (C/C++), optionally PlatformIO or MicroPython.
- Tools: USB programmer, Visual Studio Code (for coding).

Hardware Requirements:

- Microcontroller: ESP32 DevKit with Wi-Fi and Bluetooth.
- Sensors: PIR sensors for motion detection, optional light sensors (LDR).
- Motor Driver: L298N module to control DC motors.
- Display: 16x2 LCD (optional, for alerts).
- Vehicle: Small car chassis with DC motors and wheels.
- User Devices: Smartphone or computer with Bluetooth.
- Power: 3.3V for ESP32 logic and 5V–12V for motors.

Input Devices:

- PIR sensors detect heat from humans or animals.
- Optional camera for future AI-based pedestrian detection.

VII. TEST CASES

Once all the modules of the Embedded Night Vision System for Pedestrian Detection were ready, they were integrated and thoroughly tested to ensure the system works reliably. Testing was carried out at multiple levels:

- Black Box Testing
- Integration Testing
- Scenario-Based Testing

Requirement gathering and analysis:

Before starting the design, all necessary information about pedestrian detection systems and embedded solutions was collected. A detailed review of existing technologies helped in defining the system requirements, which include:

- Detecting humans and animals during night-time using PIR sensors.
- Controlling the vehicle wirelessly through a Bluetooth application.
- Using L298N motor driver for precise control of DC motors.
- Displaying detection alerts on a 16x2 LCD module.
- Ensuring low-cost, energy-efficient, and reliable operation even in complete darkness.

System Design:

The design phase focused on organizing the components, defining how data flows, and how each module interacts:.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 2, January 2026
Impact Factor: 7.67

- Hardware Components: ESP32 microcontroller, PIR sensors, L298N motor driver, DC motors, I2C LCD, and Bluetooth module.
- Software Components: Arduino IDE was used to program the firmware, which handles sensor readings, motor control, and Bluetooth communication.
- Diagrams: Block diagrams and circuit diagrams were created to show how the sensors, ESP32, motor driver, and display module are connected.

Implementation:

- During implementation, all the modules were brought together and tested:
- PIR Sensor Module: Detects infrared radiation emitted by humans or animals.
- ESP32 Microcontroller: Processes sensor input and sends control signals to the motor driver.
- Motor Driver Module (L298N): Drives the DC motors to move the car based on detection signals.
- Bluetooth Module: Allows manual control via a mobile app.
- Display Module: Shows real-time detection status and alerts.

Deployments of System:

After successful testing, the system was demonstrated using a car prototype.

- User Guidelines: Clear instructions were provided on how to operate the car and interpret detection alerts.
- User Feedback: Collected during demonstrations to evaluate usability and reliability.
- User Safety: Maintained by following safe operation protocols and ensuring accurate sensor performance.

Maintenance:

In the maintenance phase, any issues that arise after deploying the Embedded Night Vision System are identified and resolved to ensure smooth operation. This includes fixing hardware or software bugs, updating control logic, improving sensor accuracy, and addressing any user-reported problems. Regular checks and maintenance of the system components, such as PIR sensors, ESP32 microcontroller, and motor drivers, are performed to maintain reliability and performance.

User Guide: A detailed user guide is provided to help users understand the system's features, operation steps, and basic troubleshooting.

Phases	Cost / Hour (₹)	Hours	Cost Estimation (₹)
Requirement Gathering	200	5	1,000
System Design	200	7	1,400
Code Planning	200	4	800
Code Development	200	8	1,600
Implementation	200	5	1,000
Testing	200	6	1,200
Total Cost			**7,000**

Cost Estimation

The project considers costs for components like ESP32, PIR sensors, L298N motor driver, DC motors, LCD display, and miscellaneous electronics, as well as labor and development time. Estimating costs accurately ensures that the project remains within budget while delivering a functional and reliable system.

.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429 Volume 6, Issue 2, January 2026 Impact Factor: 7.67

Risk Analysis:

For this project, risks have been analyzed considering constraints related to time, quality, system performance, and hardware reliability.

ID	Risk Description	Probability	Impact
1	Internet/BluetoothConnectivity Issues	Low	Medium
2	Data Security and Privacy Issues	Low	High
3	Sensor Failure or Incorrect Detection	Medium	Medium
4	Power Supply or Hardware Failure	Low	Medium

Table: Risk Analysis

Probability	Value	Description
Low	0–30%	Risk is unlikely to occur
Medium	31–60%	Risk may occur occasionally
High	61–100%	Risk is very likely to occur

Table: Probability

Impact	Value	Description
Low	0–30%	The impact on the system is minimal and does not significantly affect pedestrian detection or overall system performance.
I Medium	31–60%	The risk may cause moderate degradation in system functionality, such as reduced detection accuracy or temporary delays in alerts.
High	61–100%	The impact is severe and may lead to system failure, incorrect pedestrian detection, or compromise of safety-critical operations.

Table: Impact

VIIi. OVERVIEW OF RISK MITIGATION, MONITORING, MANAGEMENT

Risk ID	1
Risk Description	Internet or wireless connectivity issues affecting Bluetooth communication and IoT-based data transmission in the embedded system.
Category	System Environment
Source	Wireless Communication Module (ESP32 Bluetooth / IoT Connectivity).
Probability	Low
Impact	Medium
Response	Managed by system control logic and administrator during operation.
Strategy	Ensuring reliable wireless connectivity, proper network configuration, and continuous monitoring of communication modules.
Risk Status	Occurred during testing phase.

Table: Risk-2

Software Requirement Specification:

System Implementation Software Required:

- Embedded system development environment for programming and testing the ESP32 microcontroller.
- Programming Languages: Embedded C/C++ using Arduino IDE for firmware development and system control.
- ToolsArduino IDE for coding and debugging, Serial Monitor for testing sensor outputs, and a mobile Bluetooth application for wireless vehicle control.

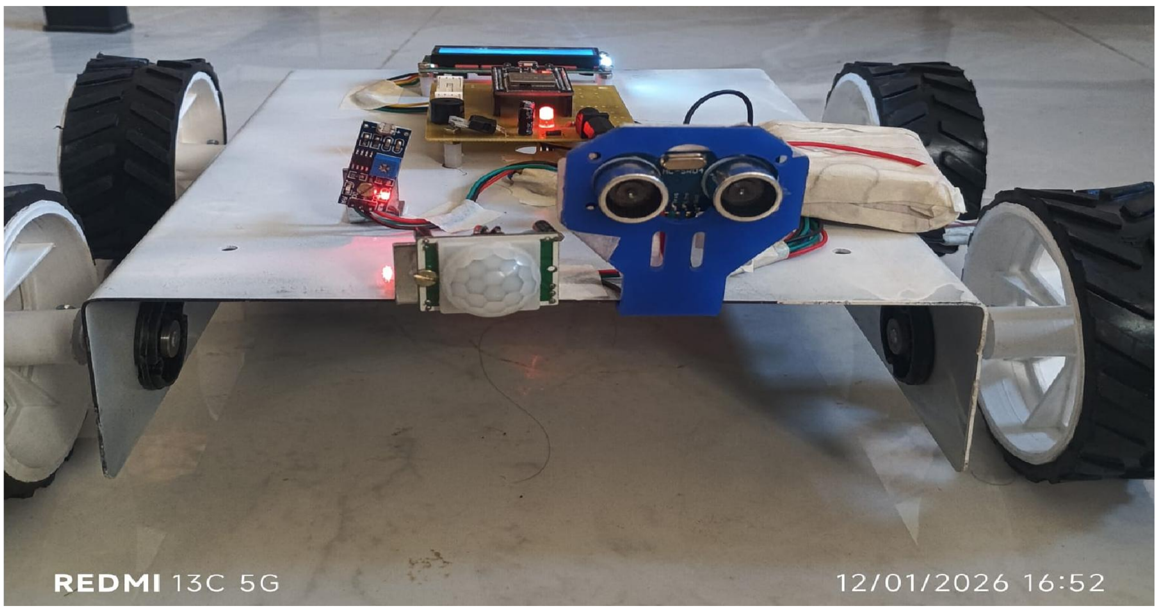
IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 2, January 2026
Impact Factor: 7.67

- Firmware and Libraries: ESP32 Bluetooth libraries and sensor interface libraries for PIR sensor data processing and communication handling.

Product Scope:

The Embedded Night Vision System for Pedestrian Detection is developed to enhance vehicle safety during night-time and low-visibility conditions. The system employs PIR sensors and an ESP32 microcontroller to detect pedestrians or animals based on infrared radiation. A prototype vehicle model demonstrates real-time detection and wireless control functionality. The proposed solution is cost-effective, energy-efficient, and reliable, offering an affordable embedded alternative to conventional night vision systems for accident prevention applications.

IX. RESULT



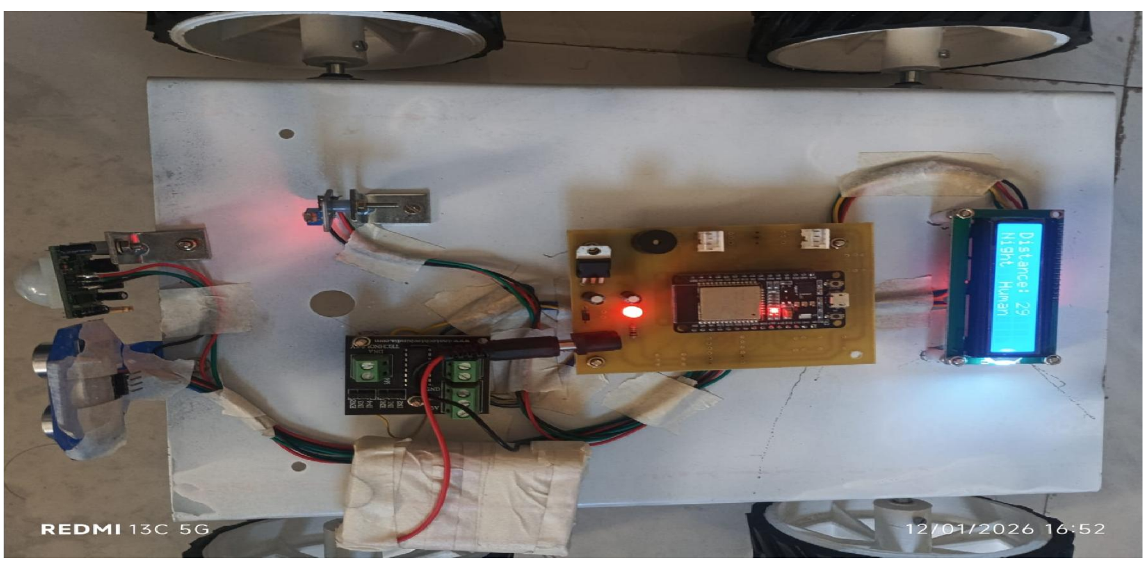


Image: Actual System

X. CONCLUSION

The Embedded Night Vision System for Pedestrian Detection offers a practical and affordable way to improve road safety during night-time driving. By utilizing PIR sensors and the ESP32 microcontroller, the system can effectively detect pedestrians and animals without relying on complicated image processing methods.The Bluetooth-controlled car prototype demonstrates how the system works in a real-world scenario, with the L298N motor driver ensuring precise and smooth motor operation. Overall, the project successfully achieves its goals of enhancing safety, keeping costs low, and maintaining reliability. This system also has potential for future improvements, such as integrating cameras, AI-based detection, and IoT connectivity, which could make it even more suitable for real-world automotive applications.

REFERENCES

[1]. Embedded Night-Vision System for Pedestrian Detection, *Int. J. Electron. Comput. Sci. Eng.*, vol. 14, pp. 10390–10398, 2022.

[2]. X. Luo, H. Zhu, and Z. Zhang, "IR-YOLO: Real-Time Infrared Vehicle and Pedestrian Detection," *Comput. Mater. Contin.*, vol. 78, no. 2, pp. 2667–2687, 2023.

[3]. Infrared Pedestrian Detection Using Improved UNet and YOLO, *Measurement*, vol. 221, Article 113442, 2023.

[4]. J. Park, B. K. Thota, and K. Somashekar, "Sensor-Fused Nighttime System for Enhanced Pedestrian Detection in ADAS and Autonomous Vehicles," *Sensors*, vol. 24, no. 14, Article 4755, 2024.

[5]. L. Zhang, W. Xu, C. Shen, and Y. Huang, "Vision-Based On-Road Nighttime Vehicle Detection and Tracking Using Improved HOG Features," *Sensors*, vol. 24, no. 5, Article 1590, 2024.

[6]. A. Rathinam et al., "Hybrid Attention for Robust RGB-T Pedestrian Detection in Real-World Conditions," *arXiv preprint arXiv:2411.03576*, 2024.

[7]. "Embedded Night-Vision System for Pedestrian Detection," *Int. J. Inf. Technol. &Comput. Eng.*, vol. 13, no. 3, pp. 347–351, 2025

[8]. Li et al., "Multimodal Fusion Transformer Network for Multispectral Pedestrian Detection in Low-Light Conditions," *Sci. Rep.*, vol. 15, Article 18778, 2025.