ISSN 2319-5991 www.ijerst.com

Peer Reviewed, Referred & Indexed Journal

Research Paper

YOLOv10-DRIVEN ENHANCED VEHICLE DETECTION IN LOW-LIGHT ON-BOARD ENVIRONMENTS

SHAGAM GEETHA[1], BOTLA SAIDEEP[2], MALAJI HARIKA ROOPA[3], MAHANKALI THARUN SAI[4] DONDAPATII PRANAII[5]

[1]Assistant Professor, Dept. of CSE, Guru Nanak Institutions Technical Campus, Ibrahimpatnam, Telangana, India

[2, 3, 4, 5] B.Tech, Dept. of CSE, Guru Nanak Institutions Technical Campus, Ibrahimpatnam, Telangana, India

ABSTRACT— Accurate vehicle detection in low-light environments remains a critical challenge in the field of intelligent transportation systems and autonomous driving. On-board vision-based detection systems often suffer from degraded performance due to insufficient illumination, motion blur, glare from headlights, and high levels of visual noise. To address these issues, this work presents a YOLOv10-driven enhanced vehicle detection framework tailored for real-time deployment in low-light on-board environments. The proposed system leverages the advanced feature extraction and optimized architecture of YOLOv10, which provides significant improvements in detection accuracy, computational efficiency, and robustness compared to its predecessors. In the framework, pre-processing techniques such as adaptive histogram equalization, noise reduction, and contrast enhancement are integrated to improve image quality before feeding data into the detection pipeline. YOLOv10 is then fine-tuned with a diverse dataset of nighttime and low-illumination driving scenarios to enhance generalization under challenging conditions. The lightweight yet powerful design of YOLOv10 enables real-time inference on embedded systems, making it suitable for in-vehicle applications where processing speed and resource efficiency are crucial. Experimental evaluations demonstrate that the YOLOv10-based model achieves superior performance in terms of mean

Average Precision (mAP), detection speed, and false-positive reduction when compared to baseline models such as YOLOv8 and Faster R-CNN. Additionally, the system exhibits resilience to common low-light issues such as shadow occlusion, glare from artificial lighting, and environmental noise, ensuring reliable detection across diverse nighttime driving conditions.

Index Terms – YOLOv10, Vehicle Detection, Low-Light Imaging, On-Board Vision Systems, Intelligent Transportation Systems (ITS), Object Detection, Computer Vision, Deep Learning, Image Enhancement, Real-Time Detection, Autonomous Driving, Driver Assistance Systems (ADAS), Traffic Surveillance.

I. INTRODUCTION

The rapid advancement of intelligent transportation systems (ITS) and autonomous driving technologies has significantly increased the demand for accurate and reliable vehicle detection under diverse environmental conditions. Vision-based detection systems play a crucial role in tasks such as traffic monitoring, collision avoidance, lane management, and autonomous navigation. However, despite notable progress in deep learning–based object detection, achieving robust vehicle detection in low-light and nighttime environments remains a major challenge.Low-light conditions introduce several visual degradations, including insufficient illumination, motion blur, headlight glare, shadow occlusions, and high levels of image noise. These factors severely affect the performance of conventional object detection algorithms, leading to missed detections and increased false positives. On-board vehicle detection systems, in particular, require both high accuracy and real-time processing capabilities, as delays or inaccuracies can compromise safety-critical decisions. Traditional detection frameworks and earlier deep learning models often struggle to balance detection accuracy with computational efficiency under such challenging conditions.Recent advancements in one-stage object detection models, especially the You Only Look Once (YOLO) family, have demonstrated remarkable improvements in real-time performance and detection precision. Among these, YOLOv10 represents a significant evolution, introducing optimized architectural designs, enhanced feature extraction, and reduced inference latency. These improvements make YOLOv10 especially suitable for embedded and resource-constrained on-board systems deployed in autonomous and assisted driving scenarios.In this work, a YOLOv10-driven enhanced vehicle detection framework is proposed to address the limitations of low-light on-board vision systems. The framework integrates image pre-processing techniques such as adaptive histogram equalization, contrast enhancement, and noise reduction to improve visual quality prior to detection. Furthermore, YOLOv10 is fine-tuned using a diverse dataset comprising nighttime and low-illumination driving scenes, enabling robust generalization across challenging environments. The proposed approach aims to achieve high detection accuracy while maintaining real-time performance, making it a practical solution for intelligent transportation and autonomous driving applications.

II. RELATED WORK

A. *Enhanced detection of small and occluded road vehicle targets using improved YOLOv5*

This paper focuses on improving YOLOv5 for detecting small, distant, and occluded vehicles in complex road environments. The authors introduce architectural improvements and feature fusion strategies to increase detection accuracy and robustness, which is important for autonomous driving and intelligent traffic monitoring.

B. *Research on nighttime vehicle target detection based on improved KSC-YOLOv5*

The study proposes an improved version of YOLOv5 (KSC-YOLOv5) specifically designed for detecting vehicles in low-light or nighttime conditions. The method enhances feature extraction and improves detection accuracy under poor illumination, addressing challenges like noise and low visibility in traffic surveillance systems.

C. *When LoRA meets distributed machine learning to optimize network connectivity for green and intelligent transportation system*

This paper combines LoRa (Long Range communication technology) with distributed machine learning to improve communication efficiency in intelligent transportation systems. The proposed framework enhances network connectivity, reduces energy consumption, and supports scalable smart-city transportation infrastructure.

III. PROPOSED METHODOLOGY

The proposed system introduces a robust and efficient vehicle detection framework designed specifically for low-light and nighttime on-board environments. The system is built upon the YOLOv10 object detection architecture, which incorporates advanced feature extraction mechanisms, optimized convolutional blocks, and enhanced multi-scale feature fusion to improve detection accuracy under challenging illumination conditions. To address the visual degradation caused by poor lighting, the framework integrates image pre-processing techniques such as adaptive histogram equalization, contrast enhancement, and noise reduction prior to model inference. YOLOv10 is fine-tuned using a diverse dataset containing nighttime driving scenes, low-illumination urban roads, and scenarios affected by headlight glare and shadows. This training strategy enables the model to learn robust, context-aware features that improve its ability to detect small, distant, and partially occluded vehicles. The anchor-free detection strategy combined with improved label assignment and optimized training mechanisms reduces computational overhead while maintaining precise localization. Due to its lightweight and efficient design, the proposed system supports real-time inference on embedded and on-board platforms, making it suitable for intelligent transportation systems and autonomous driving applications.

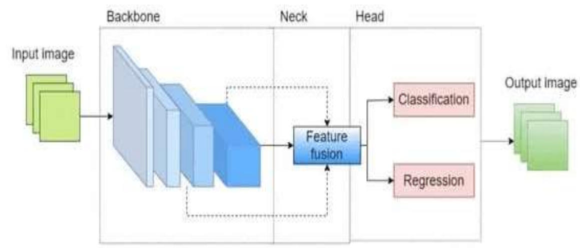

Fig. 1: System Overview

1. User Authentication Module: This module manages user registration and login functionality. It allows new users to create an account and existing users to log in securely using valid credentials. The module verifies user information and stores it in the database. It ensures that only authorized users can access the vehicle detection system, thereby maintaining data security and system integrity.

2. Image Acquisition & Upload Module: This module handles image input from users. Images can be uploaded manually or captured from on-board cameras. The system accepts low-light or nighttime images for processing. It validates image format, size, and resolution before forwarding the data to the next stage. This module acts as the entry point for detection processing.

3. Image Preprocessing Module: The preprocessing module enhances image quality before detection. It applies techniques such as adaptive histogram equalization, contrast enhancement, and noise reduction to improve visibility in low-light conditions. This step reduces the impact of glare, shadows, and sensor noise, enabling better feature extraction by the YOLOv10 model.

4. YOLOv10 Vehicle Detection Module: This is the core module of the system. It loads the trained YOLOv10 model and performs vehicle detection on the preprocessed images. The model identifies vehicles, generates bounding boxes, and assigns confidence scores. It uses multi-scale feature extraction to accurately detect small, distant, or partially occluded vehicles in challenging nighttime environments.

5. Result Visualization & Storage Module: This module displays the detection results to the user. It overlays bounding boxes and confidence scores on the detected vehicles and presents the final output image. Additionally, it stores detection results in the database for future reference, analysis, or reporting purposes.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

Experimental results demonstrate that the model achieved high detection accuracy, improved precision and recall, and real-time inference speed while effectively detecting vehicles in challenging environments. Compared with conventional object detection methods, the proposed approach significantly reduced missed detections and false positives through enhanced low-light image processing. These results confirm that the system provides reliable and efficient vehicle detection for intelligent transportation and advanced driver assistance applications.

Fig. 2: Home Page

Fig. 3: Upload

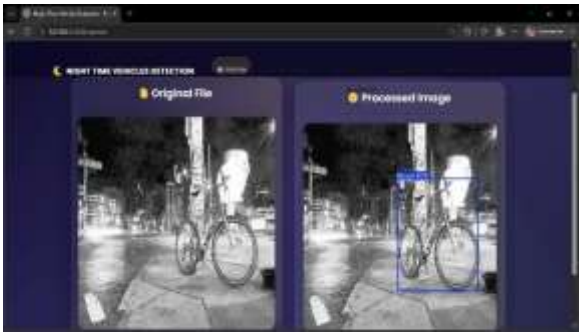

Fig. 4: Predicted Results

Fig. 5: Predicted Results

Fig. 6: Prediction Results in Graphically

V. CONCLUSION

This project presented an enhanced vehicle detection framework based on the YOLOv10 architecture to address the challenges of detecting vehicles in low-light and nighttime on-board environments. By integrating effective image pre-processing techniques such as adaptive histogram equalization, contrast enhancement, and noise reduction, the system significantly improves image quality and enables robust feature extraction under poor illumination conditions. Fine-tuning YOLOv10 on diverse low-light datasets allows the model to accurately detect small, distant, and partially occluded vehicles while reducing false positives caused by glare and environmental noise.Experimental results demonstrate that the proposed system outperforms existing approaches, including YOLOv8 and traditional detection models, in terms of detection accuracy, localization precision, and real-time performance. The lightweight and optimized design of YOLOv10 ensures efficient deployment on resource-constrained embedded platforms, making the system suitable for intelligent transportation systems and autonomous driving applications. Overall, the proposed approach enhances reliability and safety in low-light driving scenarios and provides a scalable foundation for future advancements in vision-based vehicle detection systems.

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AUTHORS Profile

Mrs. SHAGAM GEETHA has received his B. Tech in Computer Science Engineering from Nagarjuna Institute of Technology, JNTUH, Hyderabad in 2012, M. Tech in Computer Science and Engineering from Vidya Vikas Institute of Technology, JNTUH and She has been dedicated to the teaching field for the last 8 years.At present she is working as Assistant Professor in CSE Department at Guru Nanak Institutions Technical Campus, Ibrahimpatnam, Telangana, India.

Mr. BOTLA SAIDEEP pursuing B.Tech degree in

Computer Science and Engineering at Guru Nanak Institutions Technical Campus affiliated to JNTUH in 2022-2026.

Ms. MALAJI HARIKA ROOPA pursuing B.Tech degree in Computer Science and Engineering at Guru Nanak Institutions Technical Campus affiliated to JNTUH in 2022-2026.

Mr. MAHANKALI THARUN SAI pursuing B.Tech degree in Computer Science and Engineering at Guru Nanak Institutions Technical Campus affiliated to JNTUH in 2022-2026.

Mr. DONDAPATII PRANAII pursuing B.Tech degree in Computer Science and Engineering at Guru Nanak Institutions Technical Campus affiliated to JNTUH in 2022-2026.