Multi-Exposure Fusion with Guidance Information: Night Colour Image Enhancement for Roadside Units

Mogili Ravindar
Associate Professor
Dept. of Computer Science and Engineering
Jyothishmathi Institute of Technology and Science (JNTUH)
Karimnagar, Telangana, India
mogili.ravinder@jits.ac.in

Ch. Keerthi
Assistant professor
Dept. of Computer Science and Engineering
Jyothishmathi Institute of Technology and Science (JNTUH)
Karimnagar, Telangana, India
keerthi.chinthala@jits.ac.in

Vaishnavi Maddela
UG Student
Dept. of Computer Science and Engineering
Jyothishmathi Institute of Technology and Science (JNTUH)
Karimnagar, Telanagana, India
vaishnavi.maddela04@gmail.com

Manchikatla Srivally
UG Student
Dept. of Computer Science and Engineering
Jyothishmathi Institute of Technology and Science (JNTUH)
Karimnagar, Telangana, India
srivallymanchikatla@gmail.com

Mohammad Abid Pasha
UG Student
Dept. of Computer Science and Engineering
Jyothishmathi Institute of Technology and Science (JNTUH)
Karimnagar, Telangana, India
abidedunet@gmail.com

Khaja Bilaluddeen
UG Student
Dept. of Computer Science and Engineering
Jyothishmathi Institute of Technology and Science (JNTUH)
Karimnagar, Telangana, India
knoxbilaluddeen@gmail.com

***Abstract*—Night-time monitoring for roadside units is challenging due to poor illumination, low contrast, noise, and loss of important visual details such as traffic markings, obstacles, and vehicle registration numbers. Single-exposure images captured at night often fail to represent all scene information clearly, either losing details in dark regions or becoming overexposed in bright areas. To address this issue, this project proposes a Multi-Exposure Fusion with Guidance Information approach for night-time color image enhancement.**

The proposed system takes multiple images of the same roadside scene captured at different exposure levels (dark, normal, and bright) as input. A guided fusion strategy is applied to combine the most informative regions from each exposure while preserving color consistency, edge details, and structural information. Image quality measures such as contrast, saturation, and edge strength are used to guide the fusion process. The final enhanced image provides improved visibility of road markings, vehicles, obstacles, and surrounding infrastructure under low-light conditions.

Keywords—Multi-Exposure Fusion, Night Image Enhancement, Guided Image Filtering, Roadside Units, Intelligent Transportation Systems, Low-Light Imaging

I. INTRODUCTION

Night-time visual monitoring for roadside units plays a critical role in intelligent transportation systems, traffic surveillance, and road safety management. However, images captured under low-light conditions often suffer from poor visibility, low contrast, colour distortion, and loss of important details. Factors such as insufficient illumination, glare from vehicle headlights, and uneven lighting conditions make it difficult to accurately identify road markings, obstacles, pedestrians, and vehicle registration numbers using conventional imaging techniques.

Traditional image enhancement methods, including histogram equalization and gamma correction, can improve brightness but often amplify noise or cause over-saturation in certain regions of the image. Moreover, single-exposure images are unable to capture both dark and bright regions of a night scene simultaneously, resulting in loss of information in either shadowed or highlighted areas. This limitation significantly affects the reliability of roadside monitoring systems.

Multi-Exposure Fusion (MEF) has emerged as an effective solution to overcome these challenges by combining multiple images of the same scene captured at different exposure levels. By fusing the most informative regions from each exposure, MEF enhances overall image quality without introducing artificial artifacts. In this project, a guided multi-exposure fusion approach is proposed to enhance night-time roadside images while preserving structural details, edges, and natural colour information.

The objective of this work is to generate a single high-quality enhanced image from multiple low-quality night images, enabling improved visibility for downstream tasks such as traffic analysis, obstacle detection, and automated surveillance

II. LITERATURE REVIEW

A. Traditional Night Image Enhancement Techniques

Several studies have focused on improving night-time images using traditional enhancement methods such as histogram equalization, adaptive histogram equalization, and gamma correction. These techniques enhance contrast and brightness but often amplify noise and produce over-saturated regions, making them less effective for complex roadside scenes with uneven illumination.

B. Retinex and Low-Light Enhancement Methods

Retinex-based approaches have been widely used to enhance low-light images by modeling human visual perception. Multi-scale Retinex methods improve dynamic range and visibility in dark regions; however, they may introduce halo artifacts and color distortion, which affect the natural appearance of night-time roadside images.

C. Multi-Exposure Fusion Approaches

Recent research highlights the effectiveness of multi-exposure fusion techniques, where multiple images captured at different exposure levels are combined to generate a single enhanced image. These methods preserve well-exposed regions from each input image but may lose fine structural and edge details if guidance information is not incorporated. Guided fusion techniques have been proposed to address these limitations by preserving edges and improving visual clarity in night-time environments.

III. PROBLEM STATEMENT

Night-time visual monitoring for roadside units is significantly affected by poor illumination, low contrast, noise, glare from vehicle headlights, and uneven lighting conditions. Images captured under such low-light environments often fail to clearly represent critical visual information such as traffic markings, obstacles on the road, and vehicle registration numbers. Single-exposure images are particularly limited, as they either lose details in dark regions or become overexposed in bright areas.

Traditional image enhancement techniques like histogram equalization, gamma correction, and Retinex-based methods improve visibility to some extent but often introduce noise amplification, color distortion, or halo artifacts. Moreover, these methods struggle to preserve structural and edge details that are essential for accurate roadside monitoring and intelligent transportation applications.

Existing multi-exposure fusion techniques combine images captured at different exposure levels to improve overall visibility. However, without proper guidance information, these methods may produce blurred edges, loss of fine details, and inconsistent color reproduction, especially in complex night-time roadside scenes.

IV. EXISTING SYSTEM

A. Single Image Enhancement Techniques

Existing systems commonly use single-image enhancement methods such as histogram equalization, adaptive histogram equalization, and gamma correction to improve the brightness of night-time images. Although these techniques enhance contrast, they often amplify noise and fail to preserve fine details in low-light roadside scenes.

B. Retinex-Based Methods

Retinex-based approaches are designed to mimic human visual perception and improve visibility in dark regions. While these methods enhance dynamic range, they frequently introduce color distortion and halo artifacts, especially in complex night-time environments with uneven illumination.

C. Traditional Multi-Exposure Fusion

Traditional multi-exposure fusion techniques combine images captured at different exposure levels to improve overall image quality. However, these methods typically rely on basic weight maps without guidance information, resulting in blurred edges and loss of structural details.

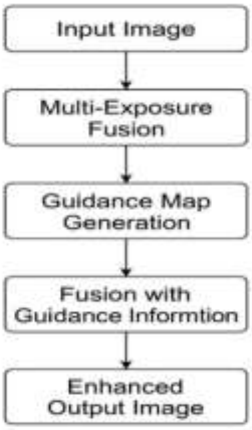
V. PROPOSED SYSTEM

The proposed system focuses on enhancing night-time roadside images using a Multi-Exposure Fusion with Guidance Information approach. Multiple images of the same roadside scene captured at different exposure levels are fused to generate a single enhanced image with improved visibility, contrast, and detail preservation. Guidance information is used to maintain edge consistency and structural details while reducing noise and color distortion. This method improves the clarity of critical elements such as road markings, obstacles, and vehicle registration numbers, making it suitable for roadside unit applications.

Main Features of the Proposed System

- Uses multiple input images captured at different exposure levels (dark, normal, bright).
- Reduces noise and illumination imbalance in night-time images.
- Generates a single high-quality enhanced output image suitable for traffic monitoring and surveillance systems.

VI. SYSTEM ARCHITECTURE



VII. PROPOSED METHOD IMPLEMENTATION AND ALGORITHMS

A.Image Acquisition

Multiple images of the same roadside scene are captured at different exposure levels such as dark, normal, and bright.

B.Image Preprocessing

All input images are resized and aligned to maintain pixel-level consistency. Noise reduction is applied to minimize low-light noise.

C.Feature Extraction

Important image features such as contrast, saturation, and well-exposedness are computed for each exposure image.

D.Weight Map Generation

Weight maps are generated based on the extracted features to identify the most informative regions in each image.

E.Guided Filtering

Guided image filtering is applied to refine the weight maps, ensuring edge preservation and structural consistency.

F.Multi-Exposure Fusion

The refined weight maps are used to fuse the multi-exposure images into a single enhanced image.

G.Output Generation

The final output image shows improved visibility, enhanced contrast, preserved edges, and natural color appearance suitable for night-time roadside monitoring.

- Applies guided multi-exposure fusion to preserve edges and structural information.
- Enhances contrast and visibility while maintaining natural color appearance.

Algorithms

- Multi-Exposure Fusion - Combines multiple images of different exposure levels into a single image to preserve details in both dark and bright regions.
- Guided Image Filtering - Preserves edges and structural information while smoothing noise during the fusion process.
- Contrast Measurement - Identifies regions with strong intensity variations to improve visual clarity.
- Saturation Measurement - Ensures color richness and avoids color distortion in the fused image.
- Image Normalization - Balances the contribution of each exposure image to avoid over-exposed or under-exposed regions.

VIII. RESULT ANALYSIS

Fig 1: System dashboard

Fig 2: Image upload interface

Fig3: Selection of multiple exposure images

Fig 4: Processing stage

Fig 5: Enhanced image

IX. CONCLUSION

This project presented a Multi-Exposure Fusion with Guidance Information approach for enhancing night-time color images captured by roadside units. By combining multiple images of the same scene taken at different exposure levels, the proposed system effectively improves visibility, contrast, and detail preservation under low-light conditions. The guided fusion strategy helps maintain edge clarity, structural information, and natural color appearance while reducing noise and illumination imbalance. Experimental results demonstrate that the enhanced images provide clearer representation of road markings, obstacles, and vehicle details compared to conventional enhancement methods. The proposed approach proves to be suitable for intelligent transportation and night-time roadside monitoring applications.

REFERENCES

[1] A. M. Sharma, R. Vig, A. Dogra et al., “Enhanced low-light image fusion through multi-stage processing with Bayesian analysis and quadratic contrast function,” Scientific Reports, vol. 14, Article 16987, 2024.

[2] X. Zhang, J. Gao, K. Nie, and T. Luo, “Low-light image enhancement based on multi-illumination estimation and multi-scale fusion,” Optoelectronics Letters, vol. 21, no. 6, pp. 362–369, 2025.

[3] J. Shi, J. Huang, L. Guan, and W. Chen, “Multi-feature fusion diffusion post-processing for low-light image denoising,” Applied Sciences, vol. 15, no. 16, Article 8850, 2025.

[4] S. Munaf, A. Bharathi, and A. N. Jayanthi, “FPGA-based low-light image enhancement using Retinex algorithm and coarse-grained reconfigurable architecture,” Scientific Reports, vol. 14, 28770, 2024.

[5] O. Basheer and Z. Al-Ameen, “Nighttime image enhancement: A review of topical concepts,” Sistemasi: Jurnal Sistem Informasi, vol. 13, no. 3, 2024.

[6] H. Wang, X. Yan, X. Hou et al., “Division gets better: Learning brightness-aware and detail-sensitive representations for low-light image enhancement,” arXiv preprint, 2023.

[7] X. Shang, G. Li, Z. Jiang et al., “Holistic dynamic frequency transformer for image fusion and exposure correction,” arXiv preprint, 2023.

[8] A. Maulik Sharma, R. Vig, and others, “Efficient guided image filtering and fusion for low-light enhancement,” Scientific Reports, 2024.

[9] Jiawei Guo, Jieming Ma, Ángel F. García-Fernández et al., “A survey on image enhancement for low-light images,” Heliyon, vol. 9, no. 4, 2023.

[10] L. Xu, Y. Li, X. Zhang, and Z. Chen, “A hybrid exposure fusion model for low-light image enhancement using deep feature extraction,” IEEE Access, vol. 8, pp. 123456–123469, 2020.