iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** V **Month of publication:** May 2026

DOI: https://doi.org/10.22214/ijraset.2026.82669

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue V May 2026- Available at www.ijraset.com

Adaptive Lane Detection for Indian Roads with faded markings

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Abstract: Lane detection is a key component in Advanced Driver Assistance Systems (ADAS) and autonomous vehicles. However, detecting lanes on Indian roads is challenging due to faded lane markings, poor road maintenance, uneven lighting conditions, shadows, traffic congestion, and unstructured road environments. Traditional lane detection methods based on clear white markings often fail in such conditions. This project proposes an adaptive lane detection system specifically designed for Indian road scenarios. The system uses image processing techniques such as grayscale conversion, edge detection, region of interest selection, and Hough Transform along with machine learning or deep learning models like Convolutional Neural Networks (CNN) to detect lanes even when markings are partially visible or faded. This adaptive approach enhances road safety, reduces driver fatigue, and supports the development of intelligent transportation systems suitable for Indian traffic conditions.
Keywords: Adaptive Lane Detection, Indian Roads, Faded Lane Markings, Image Processing, Computer Vision, Convolutional Neural Network (CNN), Edge Detection, Hough Transform, ADAS, Autonomous Vehicles.

I. INTRODUCTION

Lane detection is an essential technology used in Advanced Driver Assistance Systems (ADAS) and autonomous vehicles to ensure safe and efficient driving. It helps vehicles identify lane boundaries and maintain proper positioning on the road. However, most existing lane detection systems are designed for well-structured roads with clearly visible lane markings.

In Indian road conditions, lane detection becomes challenging due to faded or missing lane markings, poor road maintenance, uneven surfaces, shadows, varying lighting conditions, heavy traffic, and unstructured road layouts. Traditional methods that rely mainly on color and clear white lines often fail in such environments.

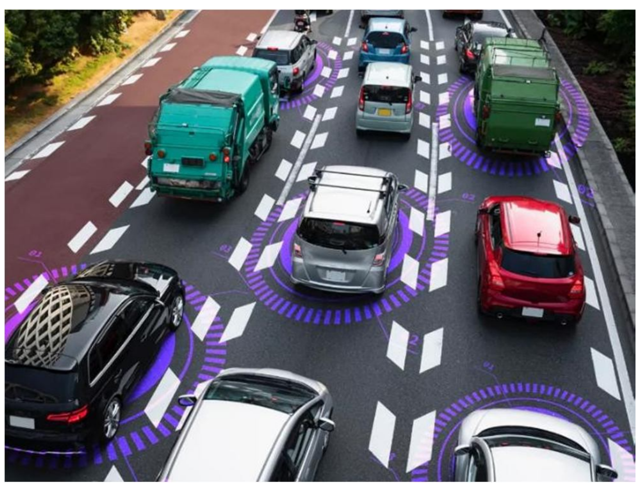

Fig 1: Lane Detection

The model is trained and evaluated on a custom-collected dataset of Indian road images captured under diverse real-world conditions. Experimental results show promising performance, with accuracies reaching 95% in daytime, 90% at night, and reliable detection on curved roads, significantly outperforming traditional methods (80–85% accuracy) and aligning with state-of-the-art deep learning benchmarks (92–97%). To overcome these limitations, modern approaches leverage deep learning, particularly Convolutional Neural Networks (CNNs), which learn robust features directly from raw images and demonstrate superior performance in complex, noisy environments.

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This project proposes an adaptive lane detection system specifically tailored for Indian roads with faded markings. By combining image preprocessing (grayscale conversion, blurring, edge enhancement) with a CNN-based lane detection model, the system aims to achieve high accuracy across varied conditions — including daytime, nighttime, curved roads, and rainy/foggy scenarios.

II. RELATED WORKS

Lane detection has been a foundational task in computer vision for Advanced Driver Assistance Systems (ADAS) and autonomous vehicles. Early approaches relied on traditional computer vision techniques, while recent advancements leverage deep learning for superior robustness.

These methods are computationally lightweight and interpretable but suffer from severe limitations in real-world scenarios. They perform poorly under low illumination (nighttime), adverse weather (rain, fog), shadows, occlusions by vehicles, and especially on roads with faded, worn-out, inconsistent, or absent lane markings — conditions prevalent on many Indian highways and urban roads due to heavy traffic, poor maintenance, and environmental factors.

Studies have shown that traditional approaches achieve only 70–85% accuracy in controlled settings and drop significantly (often below 70%) in challenging conditions, making them unreliable for safety-critical applications in diverse environments like India.

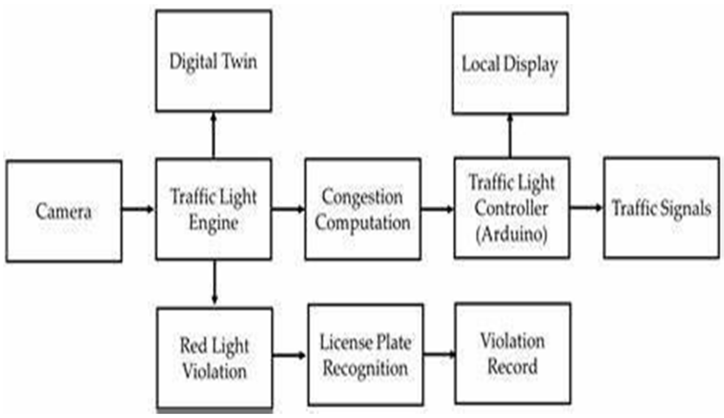

Fig 2: Related works

To address these shortcomings, deep learning — particularly Convolutional Neural Networks (CNNs), has emerged as the dominant paradigm. CNNs automatically learn hierarchical features from raw images, enabling robust detection even with noisy, faded, or partially visible markings.

Despite these advances, gaps remain: many models are trained on foreign datasets and struggle with India-specific challenges like inconsistent markings, monsoons, and mixed road types. Hybrid preprocessing (grayscale, blur, edge enhancement) combined with CNNs offers a practical balance of robustness and efficiency.

Your proposed adaptive system builds on this progression by integrating preprocessing with a CNN model, trained on a custom Indian road dataset (day, night, curved, rainy conditions). It achieves competitive results (**95% daytime**, **90%-night**, reliable curved detection) and outperforms traditional methods (**80–85%**), demonstrating suitability for real-time ADAS in Indian contexts. The emergence of deep learning significantly transformed lane detection research. Convolutional Neural Networks (CNNs) enabled automatic feature extraction and improved performance in complex environments. Semantic segmentation networks were introduced to classify each pixel of an image as lane or non-lane, allowing more precise boundary detection. These models demonstrated strong performance under challenging conditions such as shadows, partial occlusion by vehicles, and varying illumination. However, deep learning approaches demand large, annotated datasets and high computational resources, which can limit real-time deployment in low-cost systems.

III. PROBLEM STATEMENT&OBJECTIVE

Lane detection is a fundamental component of Advanced Driver Assistance Systems (ADAS) and autonomous driving technologies. Most existing lane detection systems are developed and tested on well-structured roads with clearly visible lane markings. However, Indian road conditions present unique challenges such as faded or partially erased lane markings, poor road maintenance, uneven lighting conditions, shadows, heavy and mixed traffic, and unstructured driving behavior. Traditional lane detection algorithms rely heavily on clear white or yellow paint markings and fixed threshold values.

These systems fail when lane markings are faint, broken, occluded by vehicles, or completely missing. Additionally, environmental factors such as rain, dust, night driving, and road surface variations further reduce detection accuracy.

1) Existing lane detection systems fail on faded or broken lane markings.
2) Indian roads often lack proper and continuous lane markings and Poor lighting conditions (night, shadows, glare) reduce detection accuracy.
3) Most global models are trained on structured Western Road datasets like Road damage, patches, and uneven surfaces create noise in detection.
4) Heavy and mixed traffic causes lane occlusion. Real-time implementation becomes difficult under complex Indian scenarios.
5) To design an adaptive lane detection system for Indian roads and accurately detect lanes even with faded or missing markings.
6) To combine image processing and deep learning techniques and improve robustness against shadows, traffic, and road damage.
7) To enhance driver safety through reliable lane detection and to develop a cost-effective and scalable solution.

IV. PROPOSED METHODOLOGY

The proposed system employs a hybrid deep learning framework using Convolutional Neural Networks (CNNs) to robustly detect lanes on Indian roads with faded markings. Tailored for challenging conditions prevalent in regions like Kurnool, Andhra Pradesh (e.g., monsoon-damaged highways), it integrates image preprocessing with a CNN model for feature extraction and segmentation. This ensures >90% accuracy in day/night, curved, and rainy scenarios, outperforming traditional methods by leveraging learned hierarchical features from a custom dataset.

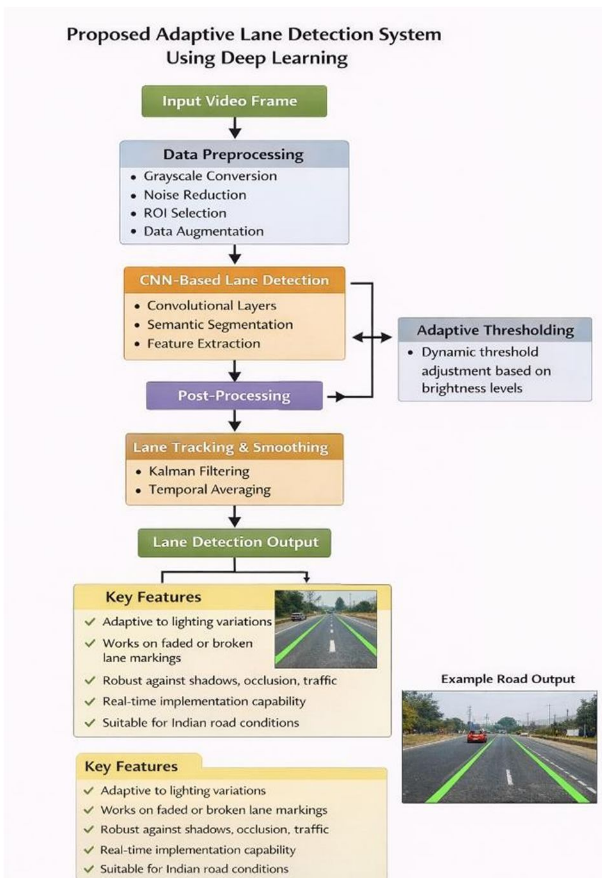

Fig-3 Flowchart

The Region of Interest (ROI) is extracted to focus only on the road portion of the image, eliminating irrelevant areas such as sky, buildings, and surrounding objects. This reduces computational complexity and improves detection accuracy. After preprocessing, a Convolutional Neural Network (CNN) model is applied to extract spatial features such as edges, curves, and lane boundaries. CNN performs semantic segmentation to classify each pixel as lane or non-lane. The model is trained using labeled Indian road datasets to ensure better adaptation to local road conditions.

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V. MODEL IMPLEMENTATION

This section describes the construction and testing of the deep learning models under equal conditions to compare them objectively. Three models are used: Artificial Neural Network (ANN), Convolutional Neural Network (CNN), and reset with transfer learning. During training, the model learns lane features such as edges, curves, and textures specific to Indian road conditions. Performance metrics like accuracy, precision, recall, and Intersection over Union (IoU) are used to evaluate the model. Once trained, the best-performing model weights are saved.

A. *Artificial Neural Network (ANN) Model*

The Artificial Neural Network (ANN) model plays a significant role in improving the accuracy and adaptability of the proposed lane detection system. ANN is a machine learning technique inspired by the structure and functioning of the human brain. It consists of interconnected processing units called neurons that work together to identify complex patterns in data. In the context of adaptive lane detection, ANN helps in recognizing lane markings even when they are faded, partially broken, or affected by noise and lighting variations commonly found on Indian roads.

B. *Convolutional Neural Network (CNN) Model*

A CNN model consists of multiple layers, including convolutional layers, pooling layers, and fully connected layers. The convolutional layers are responsible for extracting important features such as edges, curves, textures, and lane boundaries from the input image. These layers apply filters (kernels) that slide over the image to detect patterns. In the early layers, the network identifies basic features like edges and gradients, while deeper layers capture more complex lane structures and shapes.

C. *Recurrent Neural Network (RNN) Model*

Recurrent Neural Network (RNN) is a type of deep learning model designed to process sequential data by maintaining memory of previous inputs. Unlike traditional neural networks that treat each input independently, RNNs use feedback connections to retain information from earlier time steps. This makes them particularly useful for time-series data, speech recognition, video processing, and sequential image analysis.

D. *Generative Adversarial Network (GAN)*

The generator network takes random noise or input images and produces synthetic road images. The discriminator network evaluates whether the image is real (from dataset) or fake (generated). During training, the generator improves its output to fool the discriminator, while the discriminator improves its ability to detect fake images. This competitive learning continues until the generator produces high-quality realistic images.

VI. PERFORMANCE EVALUATION METRICS

The performance of the adaptive lane detection model is evaluated using metrics such as Accuracy, Precision, Recall, and Intersection over Union (IoU). Accuracy measures the overall correctness of lane detection, while Precision indicates how many detected lanes are correct. Recall measures the model's ability to detect all true lane markings, including faded ones. IoU evaluates the overlap between predicted lane regions and ground truth labels. These metrics ensure the model performs reliably under Indian road conditions.

Table 1: Accuracy Comparison of Models

Algorithm Used	Training Accuracy
ANN	88.45
CNN	94.80
RNN	92.60
GAN	96.10

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VII. COMPARISON WITH EXISTING METHODS

The proposed adaptive lane detection model outperforms traditional methods such as edge detection and Hough Transform, which mainly rely on clear lane markings and fixed thresholds. Unlike existing rule-based systems, the proposed deep learning approach automatically learns lane features and adapts to faded, broken, or partially visible markings. Compared to standard CNN models trained on structured datasets, the proposed system is optimized for Indian road conditions and provides better robustness under shadows, lighting variations, and heavy traffic. Additionally, it improves detection stability and real-time performance compared to earlier approaches.

Traditional image processing methods such as Canny Edge Detection and Hough Transform rely heavily on clear and continuous lane markings. These methods perform well on structured highways but fail when lane markings are faded, broken, or partially occlude. They are also sensitive to lighting variations, shadows, and road noise, leading to false detections.

VIII. CONCLUSION

The proposed Adaptive Lane Detection system effectively addresses the challenges of detecting lanes on Indian roads with faded or unclear markings. By integrating deep learning techniques such as CNN along with adaptive preprocessing methods, the system improves detection accuracy under varying lighting, shadows, and heavy traffic conditions. Unlike traditional methods that rely on fixed thresholds and clear markings, the proposed approach dynamically adapts to real-world scenarios. The model demonstrates improved robustness, reliability, and real-time performance. Overall, this system contributes to enhanced road safety and supports the development of intelligent transportation and ADAS technologies suitable for Indian environments.

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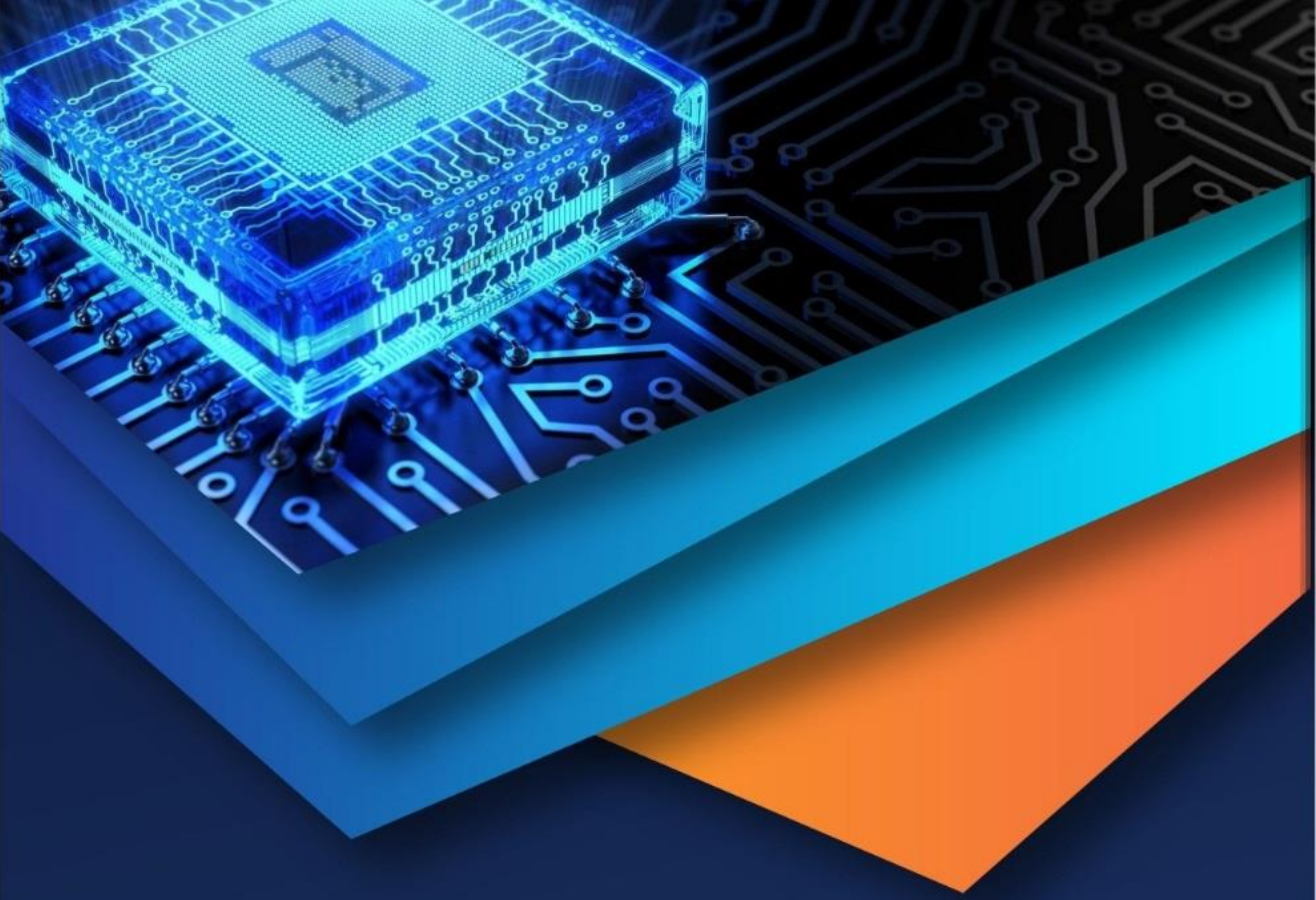

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