OPTIMIZED LANE DETECTION FOR INDIAN ROADS

A Capstone Project Phase- II Report submitted

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by

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CERTIFICATE

This is to certify that this project entitled **"OPTIMIZED LANE DETECTION ON INDIAN ROADS**" is the bonafied work carried out by **SANJAY SWARAN KUMAR DATLA, DEEKSHITH NELLUTLA, ROHITH PARSI, SAKALABHAKTULA PRANEETHA, NALLA ANKITHA, MUDUMBA RANGA YOCHANA** as a Capstone Project for the partial fulfillment to award the degree **BACHELOR OF TECHNOLOGY** in **COMPUTER SCIENCE & ARTIFICIAL INTELLIGENCE** during the academic year 2023-2024 under our guidance and Supervision.

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ABSTRACT

One of the most important technologies in advanced driver assistance systems and autonomous driving is lane detection, which enables a vehicle to go through the route and eliminate potential hazards. This project was designed to build a robust lane detection system for Indian roads because Indian roadways pose their own specific challenges such as faded or inconsistent lane markings, varied road conditions, diverse traffic patterns, and frequent obstructions. This system proposes to detect lane boundaries accurately and in real time using a combination of advanced image processing methods and computer vision tools such as OpenCV. Techniques like edge detection, Hough Transform and HSV color space for color based filtration are adapted to improve performance in diverse conditions. The project aims to optimize it for practical use on Indian roads, so it should be able to handle missing lane markings and irregular road layouts. Preliminary results show that considerable improvements in detection accuracy and robustness over conventional approaches are obtained. This project addresses the immediate need for safer and more reliable navigation tools but contributes, at large, to the adoption of ADAS and autonomous driving technologies in India, which can be a critical foundation for future intelligent transportation systems tailored for emerging markets.

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1. INTRODUCTION

Lane detection is the basic step in navigation, lane departure warning, and path planning for advanced driver assistance and self-governing vehicles. While there are many developments globally towards lane detection technologies, the systems still face challenges to adapt to the Indian road conditions as they are unique and more diverse. Indian roads have faded lane markings with worn-out or non-existent lane signs, unpredictable behavior of the traffic, and road blockages such as parked vehicles, pedestrians, and animals. Environmental conditions are an added source of difficulty, with different lighting conditions, seasonal rains, and road deterioration that interfere with reliable lane detection.

This project develops a lane detection system for Indian roads by overcoming all these difficulties. The system utilizes state-of-the-art computer vision for real-time identification of lane boundaries, even under difficult conditions. Images go through preprocessing, which removes the noise, detects features using image segmentation techniques and edge detection techniques for accurate lane identification.

The significance of the project lies in overcoming most of the difficulties faced in lane detection on Indian roads, it adds up to the greater goal of developing intelligent transportation systems for raising markets as it creates a safer and more efficient drive.

1.1 EXISTING SYSTEM:

Although many methods like edge detection and the Hough Transform are available for the traditional techniques of image processing, their performance decreases when the complexity in road conditions becomes very serious. Approaches through machine learning, consisting of algorithms like SVM, provide a degree of adaptability and flexibility. However, they are still limited concerning the manipulation of the address of numerous scenarios in real-world applications. Applications with deep learning-based approaches, including advanced U-Net and LaneNet, show significantly higher accuracies compared to conventional approaches. However, deep learning methods generally need large sets of training data and incur high computational costs to achieve their respective gains. Hybrid systems were proposed concentrating on combining the gains both in terms of efficiency as well as accuracy by providing the benefits of traditional approaches along with the advanced deep learning methods. These hybrid systems are known to work well on structured roads in commercial ADAS applications. However, they tend to face significant challenges and hardship when applied to Indian roads, characteristically less structured and more complex in nature. All these approaches, however, have crucial shortcomings in problems related to missing lane markings, high computational demand by advanced algorithms, and issues of adaptability by unstructured driving conditions.

1.2 PROPOSED SYSTEM:

a) Straight Lane Detection:

The proposed lane detection system is particularly designed to address the challenging conditions commonly seen on Indian roads. These include inconsistent or faded lane markings which cause significant impairment to visibility and cluttered views from various vehicles, pedestrians, and the unpredictable changes in light and weather. Under these conditions, lane detection is a bit more complicated, requiring a highly flexible system that would adapt to these diverse conditions yet remain accurate in its detections.

Key Features

- Straight Lane Detection:

  By applying the Canny operator and the Hough Transform for edge detection, lane boundaries can be highlighted effectively. Color-based detection using the HSV color space allows the system to adapt to variations in road surface and illumination, enhancing visibility and detection accuracy under diverse conditions.

- Real-Time Processing:

  Optimized for high-quality lane detection and tracking in real-time, the algorithm is designed to minimize latency, enabling seamless execution in practical applications.

- Indian Road Adaptation:

  The system is customized to handle challenges specific to Indian roads, such as faded, inconsistent, or partially corked lane markings; clutter on the roads; and variable weather conditions including poor lighting and rain.

- Kalman Filter and Exponential Moving Average (EMA):

  A Kalman Filter is used to predict lane offsets accurately, even in noisy or cluttered environments, while the EMA smooths lane boundary estimations, contributing to system robustness and providing a stable lane-tracking experience.

b) Curve Lane Detection:

The proposed lane detection system aims to effectively, accurately find and, follow the later frames in a continuous video feed. This is particularly focused on the Indian roads considering Indian aspects like axis or breaks between roads, lane markers, and environmental conditions. The system is designed to give accurate detection and smooth tracking of lanes through the integration of several advanced strategies.

Key Features

- Preprocessing:

  To handle the white and yellow lane markers independently, convert the input frame to grayscale and HSV color space. To make binary masks for white and yellow lanes, use adaptive thresholding. A Gaussian blur may be used to eliminate noise and shadows, increasing detection precision and lowering false positives.

- Region of Interest (ROI):

  In the lower portion of the image, where lane markings are most likely to be seen, define a dynamic region of interest (ROI). This increases detection efficiency by concentrating processing on relevant regions.

- Detecting Lanes with RANSAC:

  The Hough Transform may be used to identify possible lane lines. To ensure that outliers or noisy data do not interfere with the lane fitting process, use RANSAC (Random Sample Consensus) regression to reliably fit lines to the identified points.

- Using the Exponential Moving Average (EMA) for smoothing:

  To lessen sudden changes and provide more reliable lane monitoring in dynamic situations, use EMA to smooth the identified lane lines across a number of frames.

- Extension of Lane Lines:

  Even when only a portion of the lane is visible in the frame, extend the lane lines using the identified slope and intercept to forecast the entire lane course.

- Real-Time Processing:

  Optimized for high-quality lane detection and tracking in real-time, the algorithm is designed to minimize latency, enabling seamless execution in practical applications.

- Indian Road Adaptation:

  The system is customized to handle challenges specific to Indian roads, such as faded, inconsistent, or partially corked lane markings; clutter on the roads; and variable weather conditions including poor lighting and rain.

2. LITERATURE SURVEY

Subramani, R., Suresh, K., Cecil, D., & Vijayalakshmi, C. [1] This research paper primarily focuses on lane detection under different conditions which also includes different time scenarios like day and night due which the shadows created by the sun light and street lights could be a problem for detecting the lanes. The challenges faced in this study are poor lighting, different weather conditions and roads conditions. To solve these challenges they used preprocessing techniques and Kalman filter which have finally improved the overall accuracy of the project. The preprocessing techniques used in this paper are Gamma Correction, Region of interest, bilateral filtering, HSV filtering, Canny Edge detection and hough transform. R lane detection process clustering is used in this paper. Density Based Spatial Clustering of application with Noise is used for group relevant lanes. But the Limation of this paper is it doesn’t work for curved lanes.

Kreucher, C., Lakshmanan, S., & Kluge, K. (1998, October) [2] This paper basically developed a system that gives an alert or intimate the driver about the lane departures with the help of LOIS algorithm for detecting lanes and Kalman filter for prediction of lanes. The Primary goal or Objective of this paper is to provide a strong driving support for the driving in particular situations like drowsiness or when driver is out of focus. The most prominent algorithm used in this paper is Lois algorithm. Lois stands for Likelihood of Image Shape. This algorithm works perfect even in conditions like shadows and varying lighting sources. At the starting of predictions the algorithm works weaker but with subsequent tracking, the algorithm uses information from previous frames which results in better accuracy and performance. This system created an intimation for the driver when the predicted position lies within the predefined threshold.

Dorj, B., Hossain, S., & Lee, D. J. (2020) [3] This Paper has implemented a system that detects curved lanes which are critical for autonomous or self-driving vehicles, specially on roads which have significant turns. It combines Kalman filter with geometric models which resulted to detect and track curved lanes with better accuracy. The primary objective of this paper is to improve the safety by predicting accurate curve road turns. The faced challenges are uncertainties in the image data like noise. They used Otsu’s thresholding method and top-view image transformation for lane detection. In case of straight line hough transform is used and in case of curve lanes, it uses Kalman filter with integration of further 2 models: parabolic model-used to fit the curve with parabolic equation and Circular model- used to fit the curve with circle equation with estimating its center and radius. This work mainly helps in adjusting the steering angle based upon the road’s curvature.

Samyak Shah, A. J. (2022) [4] The paper presents a real time road lane detection system which can be used for reducing traffic accidents caused by not attentive driving. The system detects lane boundaries, and warns drivers of unintended lane departures and can be used for autonomous vehicle technologies. The proposed solution in the paper refines the current methods like edge detection, region of interest (ROI) segmentation, and hough transform for better accuracy and efficiency. It uses image processing tools like grayscale conversion, gaussian blur for noise reduction, and hough transform for lane line detection. The system differentiates the lane markings through color masks and focuses on a defined ROI to minimize irrelevant edge detections. The Hardware integration in this paper includes a Raspberry Pi Zero with a camera to process images and deliver real time audio warnings. It demonstrates high accuracy, i.e., over 96% even in non-optimal weather conditions, improving the road safety by preventing lane departure related accidents. The future scope includes improving curved lane detection, optimizing performance in extreme weather and incorporating databases for hazard recognition.

Rajakumar.Ra, 1. P. (2021) [5] The paper presents a real time road lane detection system which can be used for reducing traffic accidents caused by not attentive driving. The system detects lane boundaries, and warns drivers of unintended lane departures and can be used for autonomous vehicle technologies. The proposed solution in the paper refines the current methods like edge detection, region of interest (ROI) segmentation, and hough transform for better accuracy and efficiency. It uses image processing tools like grayscale conversion, gaussian blur for noise reduction, and hough transform for lane line detection. The system differentiates the lane markings through color masks and focuses on a defined ROI to minimize irrelevant edge detections. The Hardware integration in this paper includes a Raspberry Pi Zero with a camera to process images and deliver real time audio warnings. It demonstrates high accuracy i.e over 96% even in non optimal weather conditions, improving the road safety by preventing lane departure related accidents. The future scope includes improving curved lane detection, optimizing performance in extreme weather and incorporating databases for hazard recognition.

Shipra Singh, S. M. (2024, May) [6] The paper titled presents a system for curved lane detection, which is crucial for vehicles and advanced driver systems (ADAS), to enhance road safety and navigation. In the paper the methodology includes combining traditional image processing with advanced algorithms, overcoming challenges such as inconsistent lane markings, lighting variations, and complex road geometries. Images are preprocessed through grayscale conversion, noise reduction, thresholding, perspective transformation for bird's eye view, and Sobel edge detection to highlight lane edges. Here, the detection process uses a sliding window technique to travel lanes and a quadratic curve fitting algorithm to represent lane curvature, which calculates the radius of curvature for precise results. The testing gives high accuracy, with robust performance across different conditions, reducing errors like false positives and lane deviations. The areas are improved as the system adapts to various environments like urban roads and mountainous terrains.

The author mentioned future improvements include handling extreme weather conditions, enabling vehicle-to-vehicle communication for collective road awareness, and extending capabilities to detect pedestrian lanes and crosswalks.

Kaur, G., & Kumar, D. (2015) [7] This paper provides a brief outline of various lane detection methods which are utilized in intelligent transportation systems to improve road safety and reduce accidents. The main objective of this paper says that lane detection plays an important role in self-driving cars. This paper emphasis mainly about improving lane detection algorithms under various conditions. The existing algorithms works perfect for ideal conditions but struggles with real-world scenarios. The algorithms used in this paper is hough transform canny edge detection and bilateral filtering. Basically, this paper proposes a mixture of filtering and detection techniques to overcome the challenges.

Goel, A. (2014) [8] This paper performs different methodologies for detection of lanes in intelligent transportation systems which aims to overall improving of road safety by preventing lane deviations. Algorithms used are hough transform and canny edge detection which are effective under ideal roads but faces difficulties in real world scenarios. The advanced approaches integrates multiple algorithms with geometric models offer better accuracy. This paper identifies gaps in existing systems particularly in cases the algorithm prefers high quality images for accurate results and inability to handle extreme conditions and suggests future improvements on the algorithms for different roads and whether conditions.

Jingwei Cao, C. S. (2019) [9] The paper presents a lane detection algorithm for intelligent vehicles that are operated in complex and critical environments. The algorithm overcomes the limitations of traditional and deep learning methods by achieving. high accuracy and real time performance. It starts by correcting image distortions using camera calibration and inverse perspective transformation to provide an aerial view of the lane or view from above. The edge detection is enhanced by combining the Sobel operator and HSL color space thresholding. Lane lines are fitted using RANSAC algorithm which is based on a third order Bspline curve model, enabling strong detection even in challenging conditions. Experimental validation on road driving videos and the Tusimple dataset showed an average detection accuracy of 98.49% and 98.42%, with average processing times of approximately 21.5 ms per frame. The algorithm outclassed traditional methods and some deep-learning approaches, demonstrating excellent anti-interference, adaptability, and efficiency. It was tested under various conditions such as highways, mountain roads, and tunnels, maintaining reliable performance despite challenges like lighting, and road curvature. The study concludes that the proposed algorithm significantly enhances vehicles' safety and technical capabilities of vehicles. The future work includes aiming to improve inclusiveness and error detection to further optimize the algorithm's overall performance.

Arindol Das, [. S. (2024) [10] The paper presents a lane and curve detection system using deep learning to improve safety and for reducing accidents. It incorporated traditional computer vision techniques with convolutional neural networks (CNN) for robust lane detection, particularly for curved lanes. The process starts with data preprocessing which involves gradient calculation using Sobel and Laplacian operators, Gaussian smoothing for noise reduction, and Canny edge detection for identifying lane boundaries. After preprocessing the detected lane boundaries are mapped onto original road images for visualization. The CNN model, a Fully Convolutional Network (FCN), is used to create a binary segmentation map for lane pixels. The model undergoes training with a different types of annotated datasets, and its performance is fine-tuned using various hyperparameter optimization techniques. The approach combines the accuracy of deep learning with the speed and simplicity of traditional methods. The testing on different things demonstrates its capability to adapt to various road conditions, achieving precise detection of lane markings and curvature. In Future work, further model optimizations to enhance performance and expand usability.

3. DESIGN

a) Straight Lane Detection

A lane detection system for Indian roads typically involves following steps:

- **Data Preprocessing:** Frames from video input are processed, making them clear and uniform by resizing, normalization, improving the quality (contrast adjustment), and reducing noise. For Indian roads, the quality of images declines due to clutter and environmental conditions.
- **Model Architecture:** It uses a hybrid approach on traditional image processing- Canny edge detection, Hough Transform- as well as HSV color-based segmentation towards the lane-marking detection. Kalman filter predicts offsets with high accuracy and EMA smooths the lane boundaries for quick tracking.
- **Evaluation:** Lane Detection Consistency, Offset Stability, FPS evaluate its reliability in detecting lanes on cluttered Indian roads.

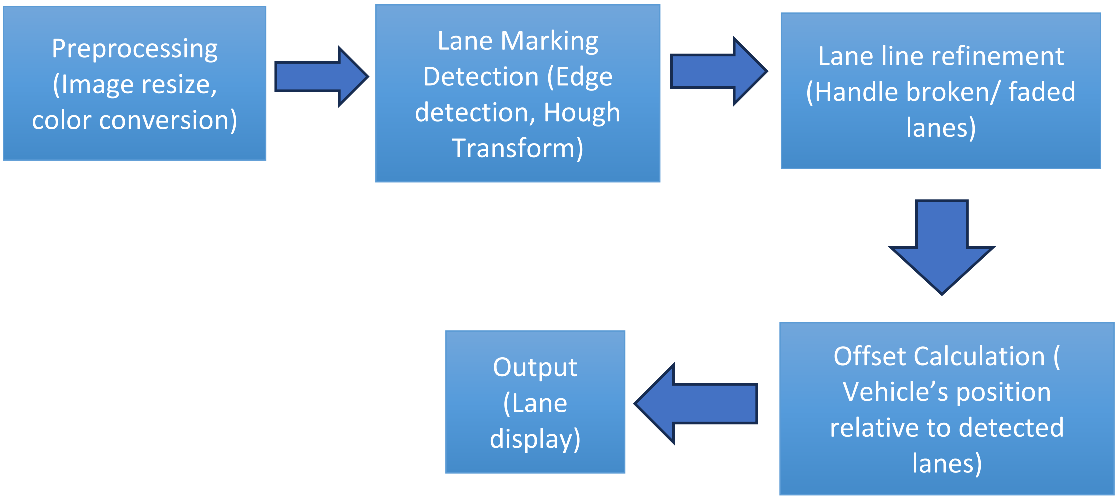


Fig 3.1 Steps in Lane Detection System (Straight)

b) Curve Lane Detection

A lane detection system for Indian roads typically involves following steps:

- **Data Preprocessing:** Frames from video input are processed, making them clear and uniform by resizing, normalization, improving the quality (contrast adjustment), and reducing noise. For Indian roads, the quality of images declines due to clutter and environmental conditions.
- **Model Architecture:** The model architecture uses the Hough Transform for lane recognition after preprocessing frames to identify white and yellow lanes. RANSAC is

used for robust line fitting in noisy data, while the Exponential Moving Average (EMA) is used for smoothing. Lastly, lane extension makes sure that lanes are continuously tracked between frames.

- **Evaluation:** The system's ability to identify lane lines without missing any is measured by its accuracy. The efficiency is assessed by real-time performance using FPS and processing time per frame. Robustness guarantees that the system operates dependably in a variety of environmental circumstances.

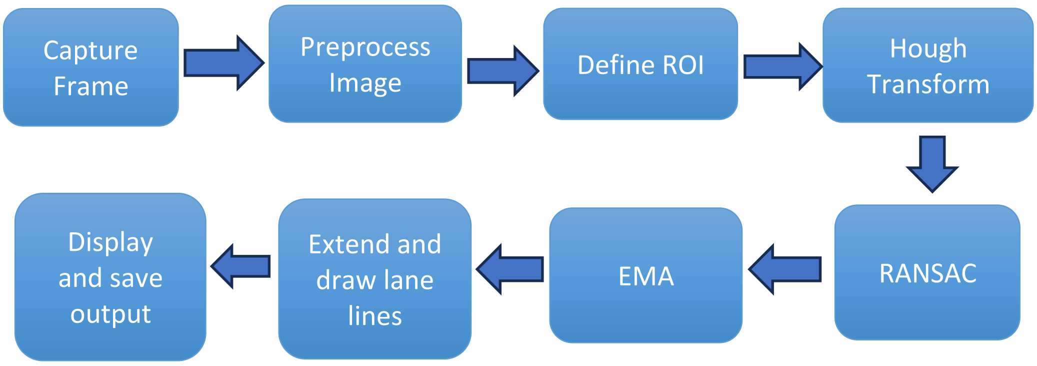


Fig 3.2 Steps in Lane Detection System (Curve)

3.1 REQUIREMENT SPECIFICATION

3.1.1 SOFTWARE REQUIREMENTS:

- Programming Language: Python (preferred), or any language that supports machine learning libraries (TensorFlow, OpenCV).
- Image Processing Libraries: OpenCV for resizing, edge detection, and color space transforms.
- Math Library: Using NumPy for the numerical operations involved in changing images and filter implementations.
- Optional: Visualization libraries like Matplotlib for plotting results of detections and metrics performance.

3.1.2 HARDWARE REQUIREMENTS:

- Processor (CPU): Multi-core processor (i5 or equivalent) for smooth operation and real-time processing.
- Memory (RAM): Minimum 8 GB, recommended; more video file processing performance enhances with more RAM.
- Storage: Storage of the processed data.
- Graphics Processing Unit: Though this component is optional, having a GPU, such as NVIDIA GTX or AMD Radeon, will significantly speed up real-time

processing, especially when considering deep learning.

3.2 UML DIAGRAM:

a) Straight:

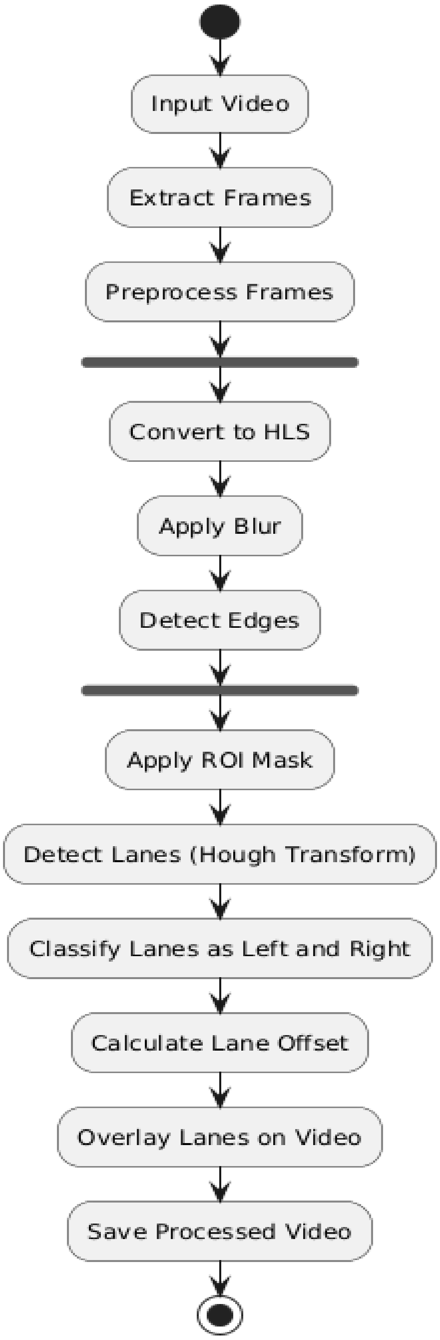


Fig 3.3 Activity Diagram

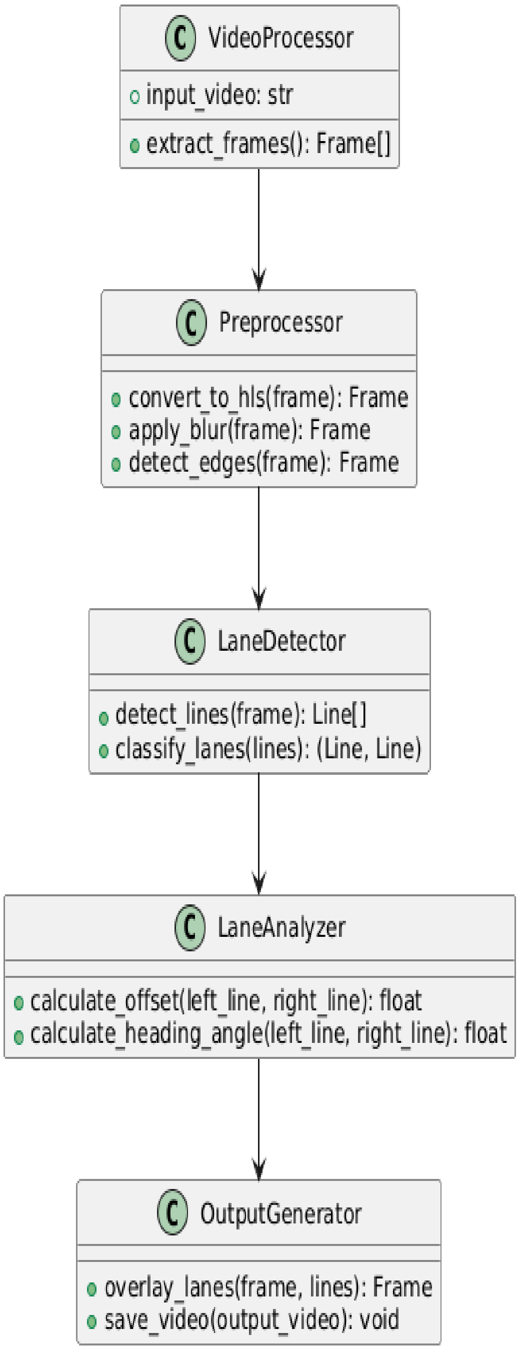


Fig 3.4 Class Diagram

b) Curve

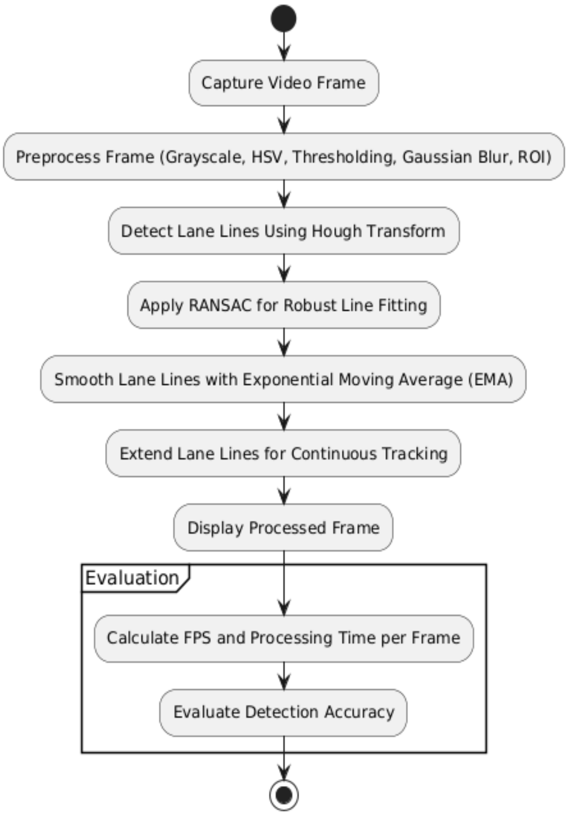


Fig 3.5 Activity Diagram

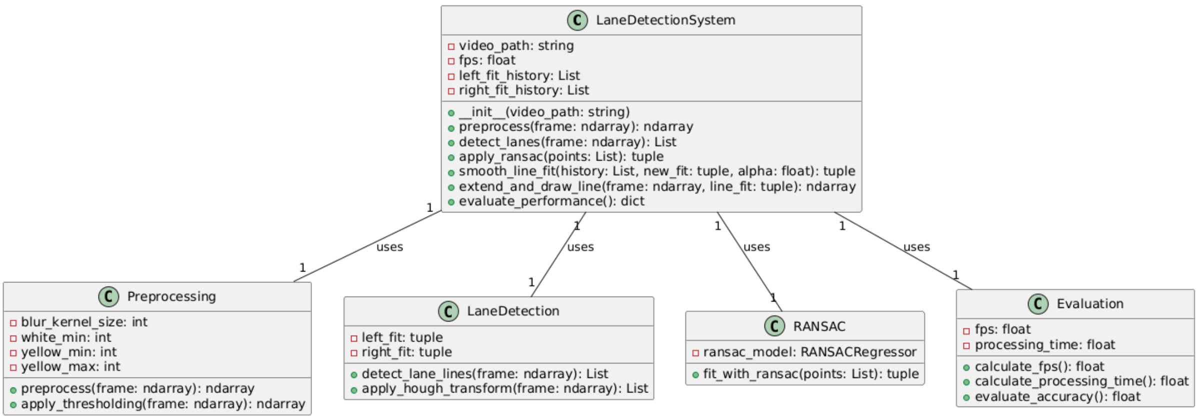


Fig 3.6 Class Diagram

4. IMPLEMENTATION

The system involves following key implementation steps:

Preprocessing:

Frames from input video are processed to enhance the observability of lane markings

- Resizing: Each image gets resized for uniformity and speedy processing.
- Contrast Enhancement: Images are made brighter for enhanced readability, particularly regarding whether faded or obscured lane marking. It is done by converting video frames into HLS color space. A binary mask is applied to isolate white areas on the frame.
- Noise Reduction: After applying binary mask, Gaussian blur is applied to reduce noise levels and smoothen the image and, therefore, making lane markings clearer.

Edge Detection:

The system, then employs algorithms for edge detection, i.e., Canny edge detector to aid in the search for edges that might be helpful to detect lane boundaries. The line found is then considered a straight lane line from an edge-detected image using the Hough Transform function.

Fig 4.1 Input image

Fig 4.2 HLS color space

Fig 4.3 Mask white and Gaussian blur

Fig 4.4 Canny edge detection

Filtering and smoothing:

The Kalman Filter is utilized by the system to make the lane detection stable and compensate for whatever type of noise or abrupt shift in the lane. This filter uses past frame data to predict the future positions of lanes, hence making the detection more accurate and reducing the effects of noise or sudden changes in lane positions.

Real-time lane tracking is done using an EMA. It stabilizes the lane boundaries due to the smoothing of the detected lane positions through time, which amplifies the capability of the system in continuous tracking of lanes across frames.

Evaluation:

The parameters- Lane Width, Heading Angle and Offset, for every 10 frames are taken to evaluate the model performance.

- **Correlation Analysis:** The parameters Offset and Heading Angle show a strong negative correlation (-0.9) indicating the inverse relationship, which could be useful for appropriate trajectory adjustments. Whereas, the parameters Offset and Lane Width have moderate correlation (0.43) indicating some dependency.

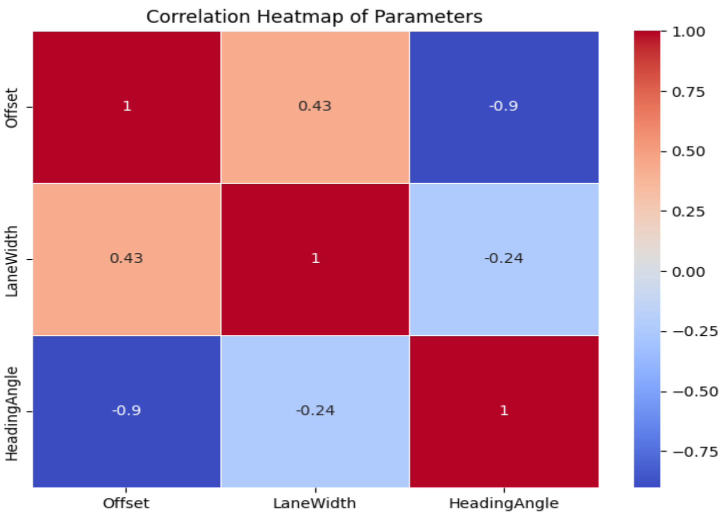


Fig 4.5 Correlation Heatmap

- **Scatter plot Interpretation:** Below is the scatter plot of Offset vs Lane Width which displays the variability in the parameters. These variations indicate road curvature, lane fading or varying lighting conditions.

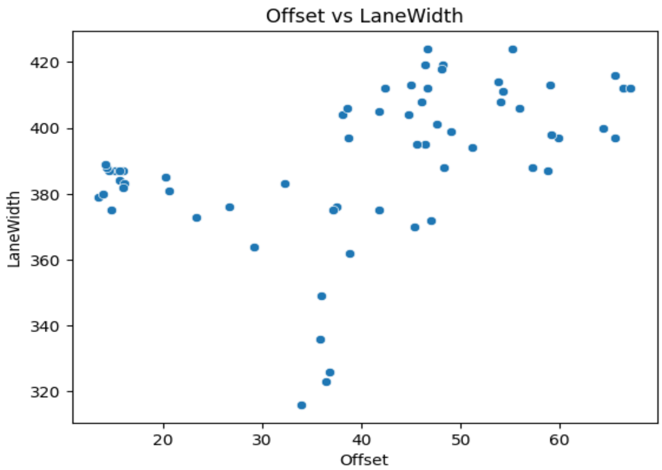


Fig 4.6 Scatter Plot

- **Behavior of Parameters:** Below is the time series graph plotted to monitor the temporal changes in the parameters and the effect of the optimizations used in stabilizing the measurements.

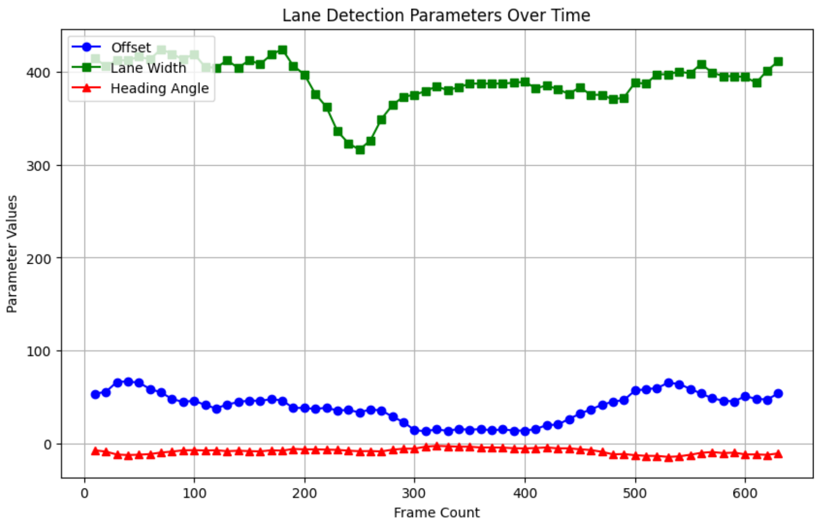


Fig 4.7 Time Series Graph

- **Lane Detection Consistency**: 99.91% consistency in detecting road lane markings under natural variations of road condition.
- **Offset Estimation Average:** 0.36 stability to predict lateral offset from lane center.
- **Lane Smoothing Track and Process:** Real-Time processing at an average of 83.32 FPS.
- **Robustness:** strong in detection of lanes of different conditions, broken or faded lines, and various road clutter types.

4.1 MODULES

Core Libraries for Image Processing:

- **OpenCV:** Used for image preprocessing (resizing, edge detection) and lane detection tasks such as Canny edge detection and Hough Transform.
- **NumPy:** Supports Performing Numerical Operations Related to Image Transformations and Matrix Computation.

Data Handling and Augmentation:

- **NumPy:** To manipulate and process the road image dataset.
- **Augmentation libraries:** To mimic diverse conditions on the road, robustly improving the model.

Data Visualization:

- **OpenCV (Real-time Visualization):** This is used to superimpose detected lanes over the video frames during real-time processing.

Lane Detection and Tracking Algorithm:

- **Kalman Filter:** Determines future lane positions; thus, no positional inaccuracies.
- **Exponential Moving Average (EMA):** This helps smooth the lane boundary and ensures stable and consistent lane tracking.
- **RANSAC (Random Sample Consensus):** Handles broken or noisy lines by fitting a reliable line model to the identified lane points.
- **Exponential Moving Average (EMA):** Prevents jitter and ensures continuous lane tracking by smoothing lane line fitting between frames.

4.2 OVERVIEW TECHNOLOGY:

a) STRAIGHT LANE

The Challenge:

Lane detection in Indian roads will pose a very challenging task as the road markings vary and the traffic density is heavy, etc. Thus, all these issues do cause problems in detecting lanes consistently in real-world or unstructured environments.

Why Hybrid Models Excel:

This kind of problem highly suited to a hybrid approach combining traditional image processing-such as edge detection and Hough Transform-with some real-time tracking algorithms like Kalman Filter and EMA. The proposed method is very efficient in the detection of lane boundaries, even with road noises and variable lighting, while ensuring real-time processing.

How the Model Works:

- **Input**: The system takes in road images or video frames.
- **Edge detection**: Canny edge detection and the Hough Transform are used in algorithms for detecting lane boundaries using techniques in image processing. Color-based segmentation is also used to outline lane markings under various lighting conditions.
- **Optimization:** The Kalman Filter serves to forecast lane positions across temporal intervals, whereas the Exponential Moving Average (EMA) facilitates the maintenance of smooth lane tracking, despite varying environmental conditions.
- **Lane Detection:** Image processing combined with tracking gives the accurate lane detection as well as real time position estimations of the lanes.

Benefits:

- **High Accuracy:** The hybrid model can obtain very high accuracy in lane detection with difficult roadway conditions such as debris, worn lane markings, and inadequate illumination. The system can process real-time video frames, so it is very feasible to use in autonomous vehicle applications.
- **Robustness:** The model withstands road noise, changes in traffic conditions, and styles of lane markings on Indian roads effectively.

  Below tables shows the results obtained by processing the same input for Kalman optimization, EMA and hybrid approach.

Optimization	*Lane Detection Consistency*	*Offset stability*	*FPS*
Kalman Filter	99.52%	16.69 px	69.68
Exponential Moving Average (EMA)	99.52%	39.74 px	81.88
Hybrid Offset (Kalman + EMA)	99.88%	0.53 px	79.94

Table 4.1 Comparison of different methods

The hybrid method outperforms both Kalman and EMA in lane detection consistency and offset stability, while maintain a high FPS. This combination could be potential approach for real-time lane detection with good accuracy and performance speed.

Materials for Further Reading:

- Hybrid models for lane detection methodologies can provide interesting insights from scholarly articles on what may come next.
- Tutorials on the usage of OpenCV and some Python libraries like NumPy and Matplotlib can implement and visualize lane detection systems.

b) CURVE LANE

The Challenge:

Road debris, inconsistent lane markers, and environmental elements like dim lighting and shadows pose problems for lane identification systems, particularly on intricate roads like those in India.

Why Hybrid Models Excel:

To provide more accuracy, flexibility, and resilience in dynamic contexts, hybrid models integrate the advantages of many approaches (such as edge detection, Hough Transform, and machine learning).

How the Model Works:

- Preprocessing includes managing shadows, converting frames to HSV, applying Gaussian blur, and identifying white and yellow lanes.
- Robust Line Fitting: Handles noisy data by fitting lines using RANSAC.
- Lane Detection: This method finds straight lane lines by using the Hough Transform.
- Smoothing: For reliable lane monitoring, the Exponential Moving Average (EMA) is used.
- Lane Extension: For continuous detection, lane lines are extended across frames.

i) STANDARD RANSAC

Introduction

A reliable regression approach for fitting models to data with outliers is called RANSAC (Random Sample Consensus). A random subset of the data is chosen iteratively, a model is fitted, and the number of data points that match the model within a predetermined threshold (inliers) is then calculated. The best-fitting model is the one with the greatest number of inliers.

Challenges

Costly to compute: Because Standard RANSAC iteratively checks random data subsets, it may be slow when there are a lot of outliers.

Lane detection inefficiency: Because RANSAC samples random points, it could take extra time to consider areas of the image that aren't relevant, which could lead to lo processing times.

ii) GUIDED RANSAC:

Introduction:

By using prior knowledge (such expected lane geometry, like slope and position) to direct the sampling of data points, guided RANSAC enhances the conventional RANSAC. This minimizes needless sampling and expedites the process by allowing the algorithm to concentrate on pertinent areas of the image.

Advantages:

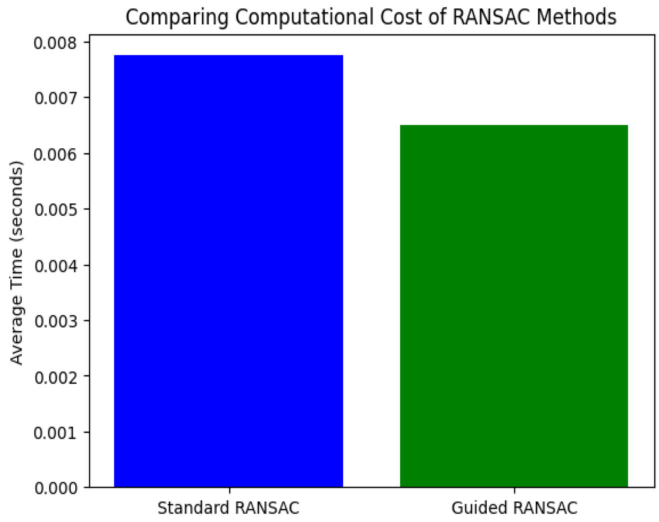
Decreased computing cost: Guided RANSAC is more effective than Standard RANSAC because it focuses on more pertinent data points and reduces the search space.

Faster processing: Guided RANSAC can process frames faster with fewer iterations and a more focused approach, which is essential for real-time applications.

Increased accuracy: Guided RANSAC is more capable than Standard RANSAC of handling noisy data and partial occlusions by employing lane geometry limitations.

Evaluation:

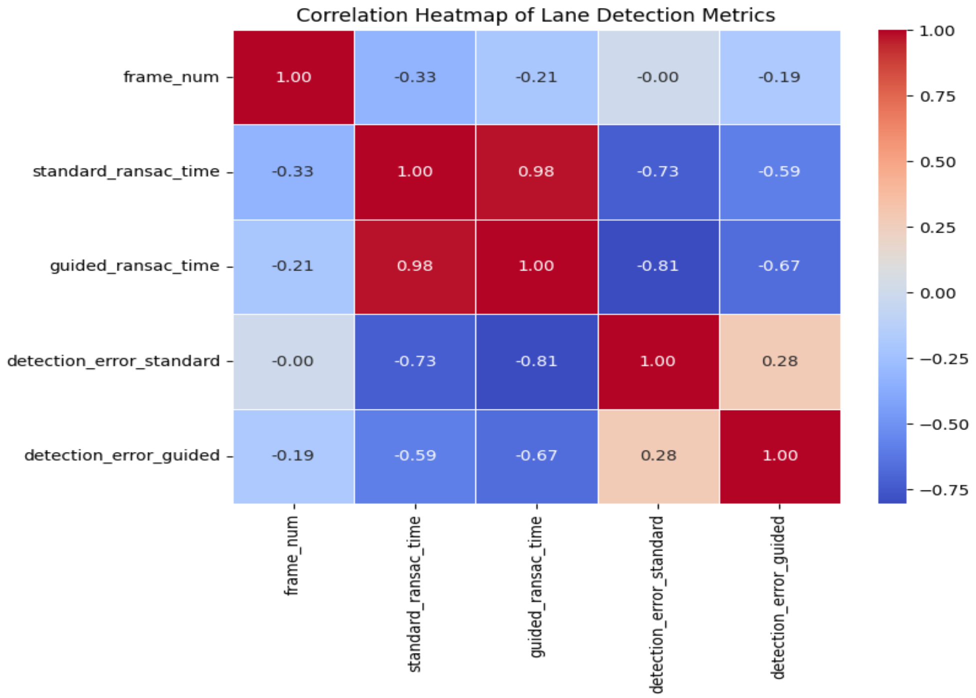
Computational Cost:



4.8 Comparing computational Cost

Correlation Analysis:

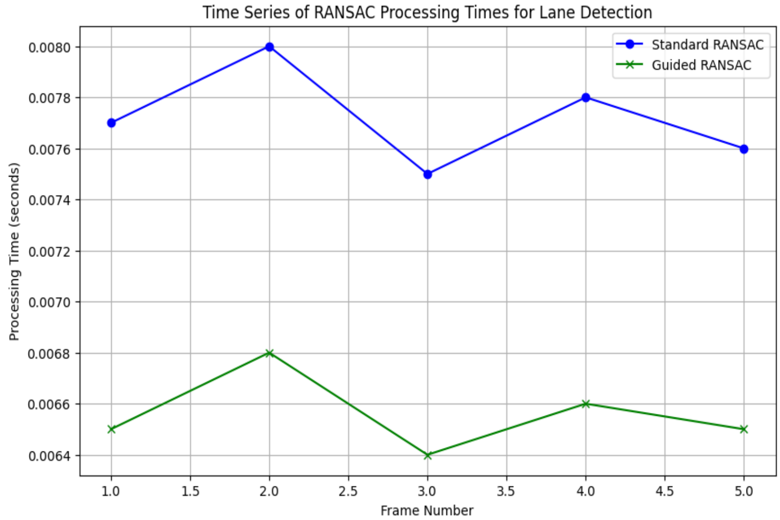
The relationship between several lane detection performance parameters, including accuracy, precision, and recall, is shown in this heatmap. It shows that Guided RANSAC outperforms Standard RANSAC in terms of both detection quality and computational efficiency, producing a better link between high accuracy and quick processing times.



4.9 Correlation heatmap of lane Detection Metrics

Time Series of RANSAC Processing times:

When compared to Standard RANSAC, Guided RANSAC exhibits a discernible decrease in computational cost in the second image. This is due to the fact that it effectively reduces the number of iterations and speeds up the lane detection process by narrowing the region of interest.



4.10 Time Series of RANSAC Processing times

Benefits:

The hybrid lane detecting system achieves excellent accuracy and real-time performance by combining the advantages of several methods. The system maintains computational efficiency while providing reliable management of damaged and noisy lane markers through the integration of Standard and Guided RANSAC. This method works well in difficult situations because it can adjust to different road conditions, such as clutter and shadows. A smooth and dependable driving experience is further ensured by the usage of Exponential Moving Average (EMA), which offers smooth lane tracking across frames. The system's adaptability is further increased by its capacity to identify both straight and curved lanes.

Materials for Further Reading:

Studies on lane detection methods (RANSAC, Hough Transform).

Articles about computer vision and autonomous driving hybrid models.

Documentation for performance improvement and real-time processing.

5. TESTING

Test Cases for Evaluation

1. **Obtaining Video Streams**: Capabilities test the system's capability to successfully acquire video streams from uploaded video recordings. Ensure that the video feed taken matches the standards necessitated for lane detection and tracking.

2. **Pre-processing Check**: Verify correct application of preprocessing operations including resizing and edge detection on every video frame. Confirm whether color space transformation (HSV) and noise reduction processes such as Gaussian blur are applied to enhance the lane detection model accuracy.

3. **Lane Detection Using Edges and Color-Based Techniques**: Assess the robustness of the system in detecting lanes in various lighting, meteorological, and roadway conditions. The accuracy of lane localization should be verified: Lane markings in video frames must be correctly represented.

4. **Offset Estimation with Kalman Filter and EMA:** Evaluate the effectiveness of the Kalman Filter in accurately estimating the car's offset from the center of the lane for contiguous frames. The effectiveness of the Exponential Moving Average in the reduction of lane boundaries and in maintaining an offset measurement.

5. **Lane Monitoring and Continuity**: The identified lane should also have been monitored without meaningful disruptions at time t consecutive frames. Test the tracking's robustness for faded or broken lanes, or when other vehicles partially obscure the lanes.

6. **Postprocessing Verification:** Confirm the correctness of lane boundary predictions and make sure that only the items related to lane markings should not appear in the output. Confirm that your final product is good, and ready for the video where it will be demonstrated indicating continuous lane tracking for viewing.

6. RESULTS

Comparision of results of previous models to our model under different conditions:

Fig 6.1 Condition: Broken Lanes

Fig 6.2 Condition: Shadows

Fig 6.3 Condition: Expansion Joints

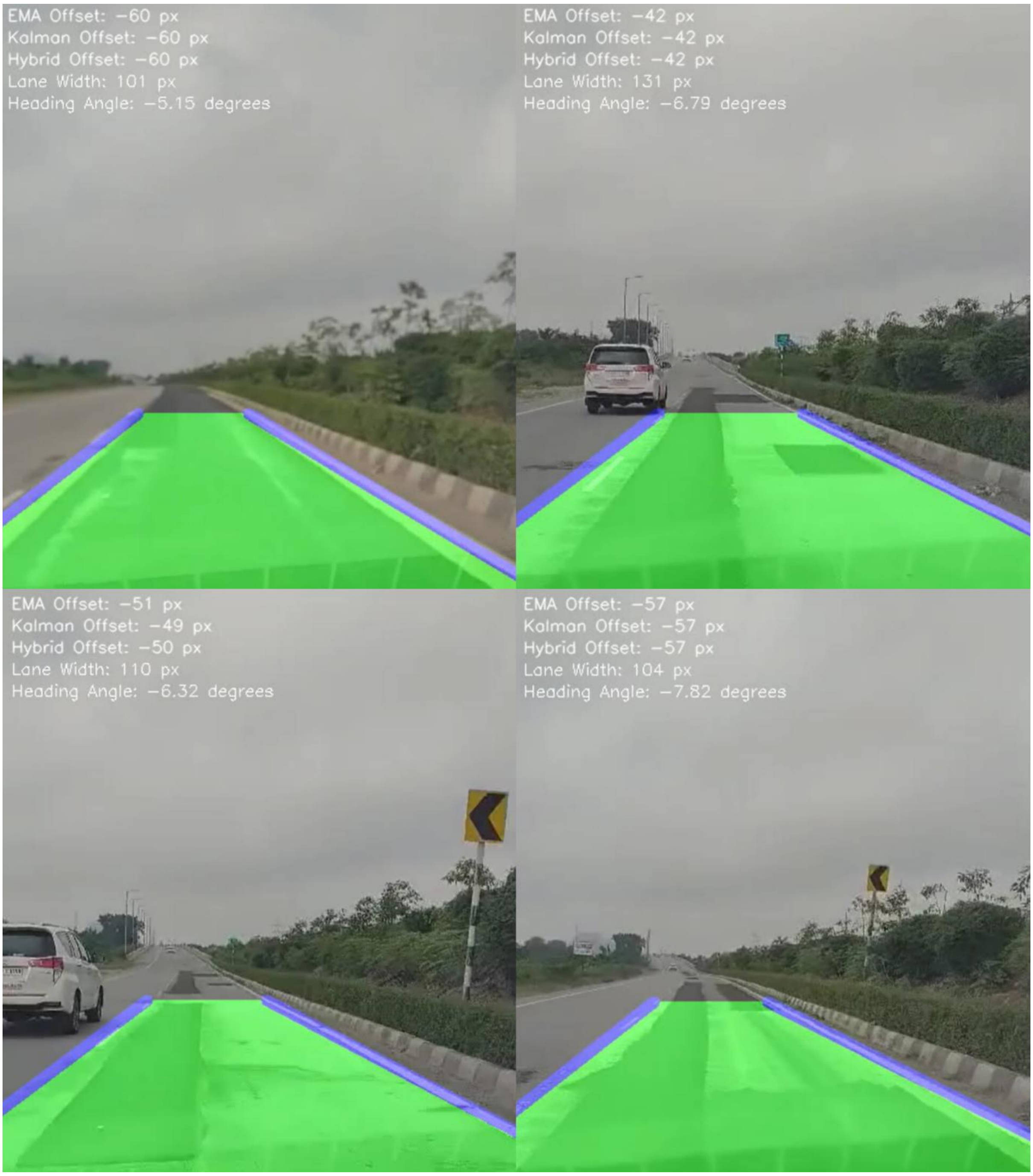


Fig 6.4 Output on Indian Roads

7. CONCLUSION

The advanced lane detection system successfully designed has been able to successfully perform real-time identification of lanes and the tracking of a vehicle. The achievement was specially impressive considering the generally adverse road conditions, such as bad lane markings, the incidence of shadows, and the presence of expansion joints on the road. The proposed model, which provides a combination of conventional image processing methods with hybrid filtering techniques, is eligible to clearly detect the boundaries of lanes. In addition to this, it also makes accurate calculations of offsets so that the vehicle is exactly in the center of its allocated lane at any point of time in its journey.

This particular approach presents an exciting and motivational solution towards enhancing road safety and simultaneously facilitating the design and incorporation of autonomous driving technology. It is significant because vast and challenging road conditions are often found on Indian roads where general road environments can be extreme in many areas. Results obtained from this experiment show high detection and excellent real-time processing capabilities. These are very important results because they provide a basis from which further improvements can be engineered, especially targeted towards achieving enhanced accuracy in lane detection and overall stability in the systems. Some of the possible opportunities for interventions could be deep learning techniques that maximize the adaptability of such systems. The result would significantly contribute to the overall reliability of these intelligent driving technologies, ensuring better resilience in different conditions under which driving becomes operational.

8. FUTURE SCOPE

The development of a Lane detection system utilizing OpenCV and other technologies offers numerous opportunities for future research and advancement:

- **Deep Learning Improved Lane Detection:** Techniques such as CNNs, which evolved into Transformer-based architectures in the newest deep learning architecture, could significantly improve the accuracy level of lane detection and allow following curvy roads, complex structures, and lanes that are poorly marked.
- **Improving Adaptability to Varying Road Surfaces:** This system would be supposed to improve on the functionality of lane detection responding to adverse conditions such as ill lit roads, extreme weather, heavy traffic, and others.
- **Real-time Performance Optimization:** It can be further optimized to cut down processing time and resource consumption to achieve flawless real-time lane detection for applications in autonomous driving and ADAS.
- **Dynamic Lane Change and Lane Obstacle Detection:** Developing the model for dynamic lane changes such as lane splits, exits, or merging lanes and detecting lane obstacles would make the system highly versatile and straightforward vehicle navigation.
- **ITS Integration:** V2I communication integration would therefore allow connectivity with the smart city infrastructure and, thereby, enable coordinated traffic management, adaptive routing, and automated response to lane usage and flow in traffic.
- **Collection of Data and Ongoing Learning**: Employ mechanisms of ongoing learning where the model is refreshed at regular intervals by new data taken from multiple different environments. This way, the model remains fresh and thus effective in different types of roads and geographies.
- **Real-time Feedback for Driver Assistance:** Even with real-time feedback, lane deviation or potential lane departure warnings can easily support driver safety and enhance the current ADAS technologies provided in commercial vehicles. Exploring these future directions might make your lane detection project even significantly contribute toward the development of road safety, smart transportation, and autonomous driving systems.

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