KLE Technological University
Creating Value, Leveraging Knowledge
Dr. M. S. Sheshgiri Campus, Belagavi

Department of Electronics and Communication Engineering

Report on Machine learning Course Project

PathPilot-OpenCV-Based Lane Detection For Safe Navigation

By:

1. **Akash Potdar** USN: 02FE22BEC003
2. **Ayan Kudachi** USN: 02FE22BEC013
3. **Pallavi Lad** USN: 02FE22BEC046
4. **Vaibhavi Patil** USN: 02FE22BEC048

Semester: V, 2024-2025

Under the guidance of
Dr.Arun Tigadi

Abstract

Safe navigation is enabled by lane detection, which is an important component of autonomous vehicles and Advanced Driver-Assistance Systems (ADAS). Existing methods struggle with accuracy and robustness because of variations in lightning conditions, road-types and weather conditions. Due to these challenges there is a need to develop a efficient lane detection framework to overcome these problems. The aim is to develop a lane detection system using OpenCV which improves accuracy and robustness in various environments and different road types. Traditional computer vision techniques have been used. OpenCV is used for image preprocessing, applying canny edge detection and Hough transform to detect lanes. Lane region segmentation is used for accurate detection. It processes the images effectively and performs feature extraction, in addition to that it also improves performance. The model is trained by a dataset having various images including different road conditions and environmental variations like foggy scenarios, nighttime, daytime etc. Experimental results shows improved accuracy and robustness in various lightning conditions, including daytime, nighttime and foggy scenarios. The model achieves real-time performance, processing 63.66 frames per second with an accuracy of 92%. This project efficiently and accurately detects lanes using OpenCV. The proposed approach shows potential to improve safety in autonomous navigation and ADAS applications. Future work will focus on integrating this system with other ADAS components, exploring its applications in real-world scenarios and exploring transfer learning techniques.

Keywords—Lane detection, autonomous vehicles, ADAS, OpenCV, Canny edge detection, Hough transform, real-time performance,robustness.

Contents

List of Figures

List of Tables

1 Introduction

1.1 Overview

In the recent year, there have been increase in number of vehicles as a result there is increase in traffic, due to this accident are taking place more in number. By taking concerns of the accidents, as per most recent data available from the year of 2022 Ministry of Road transport highways (MORTH) Annual Road Accident Report. In the year of 2022 the total accidents only in India around 400,000 to 450,000 road accidents. The number of death taken place around 150,000 to 160,000, due to factors like road conditions, traffic violations vehicle volume. Injuries taken place might be around 450,000to 500,000 based on the ratio of 2019. As per the details the two wheeler accidents took place more around 40-50% of total accident Out of the total accidents about 7-10% of accident are of Reckless driving. To overcome this accidents traffic problem, we come up with the solution lane detection by using OpenCV.

Lanes are divided sections of road marked by white lines usually they are marked in two in number OpenCV is a computer vision library,it is powerful widely used open source library which is designed to provide computer vision tools for real time image processing task. It has 2500 optimized algorithms.OpenCV has been identified as a versatile framework for implementing lane detection algorithms due to its extensive image processing capabilities[22]. The OpenCV has variety of computer vision tasks such as Image processing, face recognition, object detection and recognition ADAS play crucial role in enhancing road safety by assisting drivers in tasks like lane keeping, blind spot detection, collision avoidance[1].The authors in [20][3] intended to improve the realibilty of self-driving carts in complex settings contributing to advancement of autonomous vehicle technology.

1.2 Terms to be known

Computer vision: Computer vision is a branch ofArtificial Intelligence (AI) and computer science, which is used to analyse and interpret visual data, such as images and videos.It also teaches the machine to recognize various other parameters such as objects, faces,and patterns as well as to understand scenes and actions . Computer Vision has many practical application which includes self driving assistance for autonomous driving,it is used for face recognization for security purpose, in health care it is used for X-ray and MRI's for diagnosis.it also aids in agriculture for crop monitoring.This is fast growing field with very much opportunity for future scope.

1.3 Problem Statement

The main aim is to process the pre-recorded video to locate and track the lane markings on the road. Each image of the video is processed through particular transformation and image smoothing techniques to create the better view of the road. After the process of transformation particular image processing techniques are applied to detect and mark the lane trackers on the road. This is mainly used for autonomous driving of vehicle, focusing on confirming the accurate lane detection and to follow certain rules, even in some offline analysis scenarios.

1.4 Objectives

In today's world one of the biggest problem is road accidents which are happening vary often due to various reasons such as bad roads, foggy weather, drivers tiredness and various other reasons. Road linkage offers the best connections for transportation and is plays very important role in the development of any country. Lane detection plays an important role in self driving systems.Lane detection algorithms aim to improve the efficiency and accuracy of detecting road lane markings, which is vital for autonomous vehicles and ADAS [13] it eliminates the danger of the car entering another lane and set the path for self-driving. It reduces the risk of car entering in different lane and it sets particular path for self-driving. Based on the applications the goals may differ for the study and detection of lanes, typically some of the objectives are:

1. One of the important factor is road lane detection is to boost roads safety by identifying lane markings. This can help in reducing the road accidents and providing better driving experience.
2. Improving autonomous driving technology: The ability of autonomous vehicle to move along the roadways and diminish errors provides better results for lane detection. By improving the accuracy and effectiveness of the algorithm, autonomous cars can make safer driving decisions, such as lane changes and other parameters to avoid collisions.
3. Lane Identification: This process helps the vehicle understand its position in relation to the road markings, whether they are solid or dashed lines. Accurate lane identification is essential for guiding autonomous or assisted driving systems to stay within designated lanes, especially in complex road environments. The technology relies on image processing algorithms that analyse visual data, even in low visibility or challenging conditions, ensuring precise lane boundary detection for safer navigation.
4. Lane Tracking:Lane tracking involves continuously monitoring and identifying lane markers on the road to assist in guiding a vehicle's movement. This is typically achieved using cameras or radar sensors that provide real-time visual data. The lane detection system processes this data to locate the vehicle's position within the lane and makes necessary adjustments, such as steering or speed control, to ensure the vehicle stays centred. This helps in continuously keeping the vehicle centred at the particular lane. There are many other objectives related to the lane detection these are the some of the important objectives which need to be improved to develop a most precisiable model.

2 Literature Survey

Lane detection is crucial factor of autonomous vehicles. As a result, many researches have taken place on this particular topic and various techniques have been developed for efficient lane detection.

Manav Garg et al. [5] outlines the system that is focused at enhancing road safety through lane detection using computer vision libraries. In this project challenges are to detect lanes under poor visibility, such as night time or low voltage dim light conditions, by using advance techniques like image contrast and edge detection for accurate lane recognition. The methodology used in this project includes Canny edge detection, Gaussian blur for noise reduction, region-of-interest extraction and transformation for identifying lane lines. This system aims to reduce accidents by preventing lane detection and improving autonomous driving capabilities.

Ali Karimoddini et al. [6] developed a CNN model for lane detection .Sliding window approach is used for efficient feature extraction .The network consists of three convolutional layers and one max-pooling layer .The model is implemented using OpenCV and it was trained and tested using KITTI and Caltech dataset .It was observed that the system was capable to process 28 frames per second .The algorithm used here assumes that the lanes are parallel and of consistent lane width .As a result this would limit the performance in roads which have curved lane width.

Zakir Baytar et al. [16] proposed a improved approach for autonomous vehicle control for lane detection .They mainly focused on tracking the lanes and also extended their work in following target vehicles and designed a system which is also able to respond to traffic signs such as stop signal and traffic lights .The model is implemented using deep learning and computer vision. The dataset used is unity3D simulation and also real-world data is used .The limitation of this system is it relies on basic approximation and lacks advanced decision making algorithms to handle complex scenarios.

Maria C. Brad et al. [17] focused on Hough line detection ,vanishing point computation and focusing on region of interest. A U-Net neural networks is used for segmentation for keeping it in the centre of the road for better analysis and detection of the lane,it is implemented using python and OpenCV libraries .This papers aims in reducing road accidents and provide the better driving experience.

Anmol Sharma et al. [18] proposed the lane detection methods for critical driver -assistance systems, the sensor focuses on structured roads. The side two edges are detected and useful algorithms were implemented. The side lane is compared using ROC and DET curve to get smooth and accurate result. The methodology includes OpenCV libraries to detect the boundary line and run the car, distortion removal and edge detection. The system identifies the lane marking and position of the car is estimated using sliding window. This model struggle with demanding like rain, shadows and poorly marked lanes Dajun Ding et al.[4]. Sujay Bharadwaj et al. [21] mainly focuses on accurate lane detection using OpenCV. In this paper the main aim is to smoothen the image using Canny Edge detection by varying the sigma factor and only the required edges are considered. Further they used Hough transformation for line detection for better robustness and also to reduce noise, and have used Gaussian blur with Canny edge detection for reduction of the noise and better resolution of the frames .Segmentation is also used for keeping the object in the centre of the lane. The system mainly aims in providing better self driving assistance and minimizing the road accidents.

Astika Istinigram et al.[9]developed a lane detection system to function effectively under challenging conditions including rain and low illumination at night. The study employs Hough transform method to detect lane markings on roads. The authors focused on preprocessing techniques to enhance image quality and reduce noise. Rodi Murad et al.[14] implemented computer vision techniques using OpenCV to detect lanes, employing methods such as colour space transform, image filtering, blurring etc.

Youcheng Zhang et al.[23]explored the deep neural networks to enhance accuracy and robustness of lane detection. The authors analysed various approaches, including convolutional neural networks, attention mechanisms, multi-tasking learning. The study concludes with insights into future directions, emphasizing the potential of deep learning to improve intelligent transportation system. Further, Kumar Shubham Raghav et al. [19]andArun Pandian et al.[2] presented an intelligent system designed to assist drivers in various driving tasks, using a combination of internet of things, computer vision and machine learning.

Some other researchers[8][10]also worked on similar lines focusing on computer vision techniques for detecting road lane markings. The commonly used algorithm is canny edge detection and models are implemented using OpenCV. The systems proposed here relay on static thresholds making them sensitive to changing road textures and also struggle with variations in environmental conditions.Also, some systems were proposed for detecting obstacles and traffic assistance[15][7][11] [12]. Future work includes extending the methods to unstructured roads and making the models more efficient in adverse weather conditions like rain, fog, night-time. By addressing these future directions lane detection can become more versatile and robust which will enhance autonomous vehicles and ADAS.

3 Methodology

This section presents the methodology used to develop the lane detection system. A overall framework of the system is included in Fig.1. Our approach includes taking the prerecorded video as input after that sizing of images is done. Later it includes canny edge detection algorithm, then segmentation and Hough transform is performed and then in output the video is produced with detected lanes.

3.1 Block Diagram

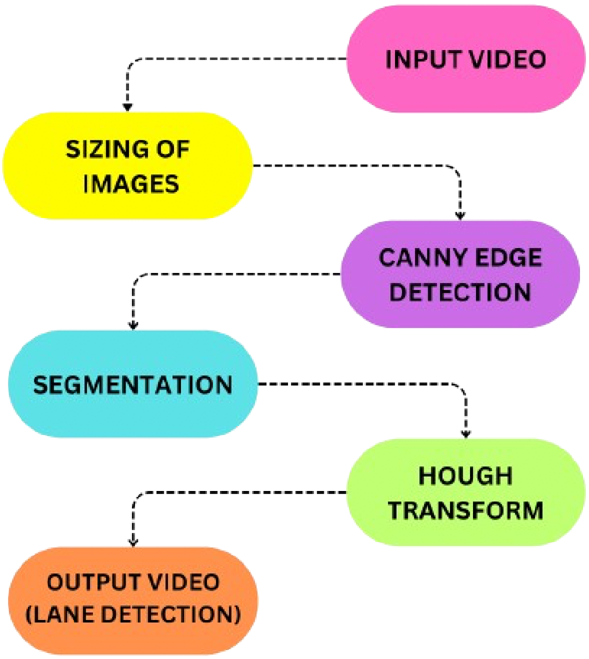

Figure 1: System model for Lane Detection

OpenCV: OpenCV is widely used computer vision library that provides a common infrastructure for a computer vision applications. It provides a wide range of computer vision algorithms for image and video processing. OpenCV provides functions for feature detection and description, including corner detection, edge detection and feature extraction. Also it helps to recognize the lanes on the roads.

Image preprocessing: The input image is first converted to grayscale, which simplifies the image by representing the brightness of each pixel as a single value. To reduce noise and smooth the image, the Gaussian Blur algorithm is applied. This step helps minimize false edge detection in later stages. Smoothing an image involves adjusting a pixel's value to be closer to the average intensity of its neighbouring pixels. The Gaussian Blur achieves this by using a kernel—a small matrix of numbers that follows a normal distribution. The kernel moves across the image, replacing each pixel's value with a weighted average of its neighbours. This process reduces noise and creates a smoother overall appearance. The mathematical expression used for this its shown in equation 1.

$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \tag{1}$$

Canny edge detection: The image is then passed through canny edge detection algorithm to detect the edges in the image where pixel intensity changes abruptly (e.g lane markings).Canny edge detection can detect weak edges that may not be detected by other edge detection algorithms .It has high ability to detect weak edges, reduces noise and provides good edge localization which helps to improve the accuracy of lane detection. Canny edge detection algorithm first simplifies the image by removing color information and then computes gradient intensity and directions by using following equations:

$$G_x = \frac{\partial I}{\partial x}, \quad G_y = \frac{\partial I}{\partial y} 2$$

Gradient magnitude:

$$G = \sqrt{G_x^2 + G_y^2} 3$$

(2)

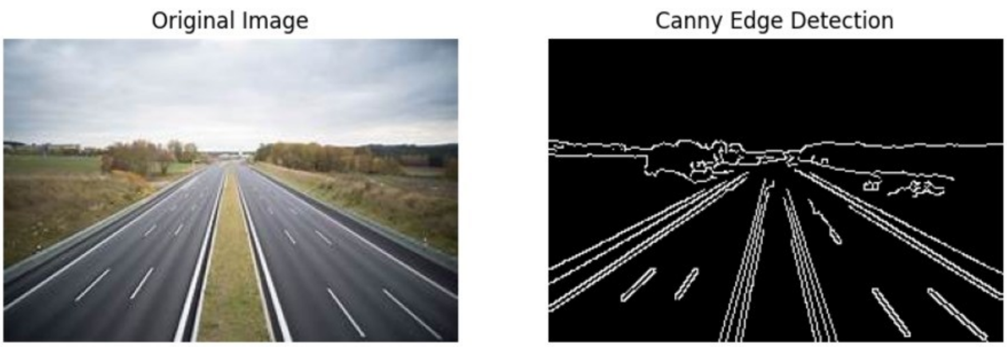

Figure 2: Canny edge detection

Region of Interest: Region of interest (ROI) is a rectangular or polygonal region in an image of particular interest or relevance for a specific application or analysis. ROI is used to focus on the region of the image where the lanes are most likely to be detected.It creates a mask with the shape of the ROI ,here triangle has been created.Further the mask is applied to edge detected image using bitwise AND .Then the ROI is segmented combining different techniques.The ROI is thresh-holded to separate the lanes from the rest of the images and then the segmentation results have been refined. The result of ROI is shown in Fig.3

Hough Transform:The image is then passed through Hough transform.The Hough Transform is mathematical technique used in computer vision to detect geometrical shapes like lines,circles or ellipse in an image .Here it is used to identify the lane lines in the image by looking for straight lines.

In polar form, the equation of a straight line is as follows:

$$\rho = x \cos \theta + y \sin \theta 4$$

where:

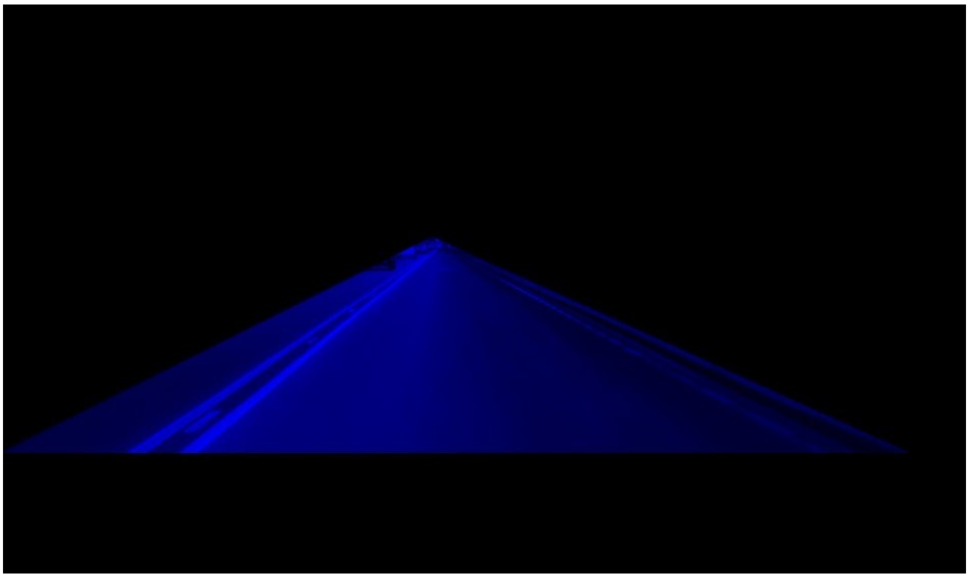

Figure 3: Region Of Interest

- ρ: The perpendicular distance from origin to the line.
- θ: Angle of the perpendicular from origin to the line.

This representation avoids issues with vertical lines, which cannot be expressed in slope-intercept form ($y = mx + c$).

Line averaging is performed which smoothens and averages multiple detected and then classify the line as left or right based on the sign of the slope. The averaged lines are then extended to fix the span of vertical range in an image.Use the line equation shown in (5)

$$x = \frac{y - b}{m} 5$$

Then, calculate coordinates (x_1, y_1) and (x_2, y_2) based on the image height. After applying the hough transformation to the input video it takes the frames from the video to calculate the boundries of the lanes.Then after calculations it marks the lanes with a green colour marked lines.This shows the difference between the input frame and hough tranformed output frame which can be seen in Fig.5.

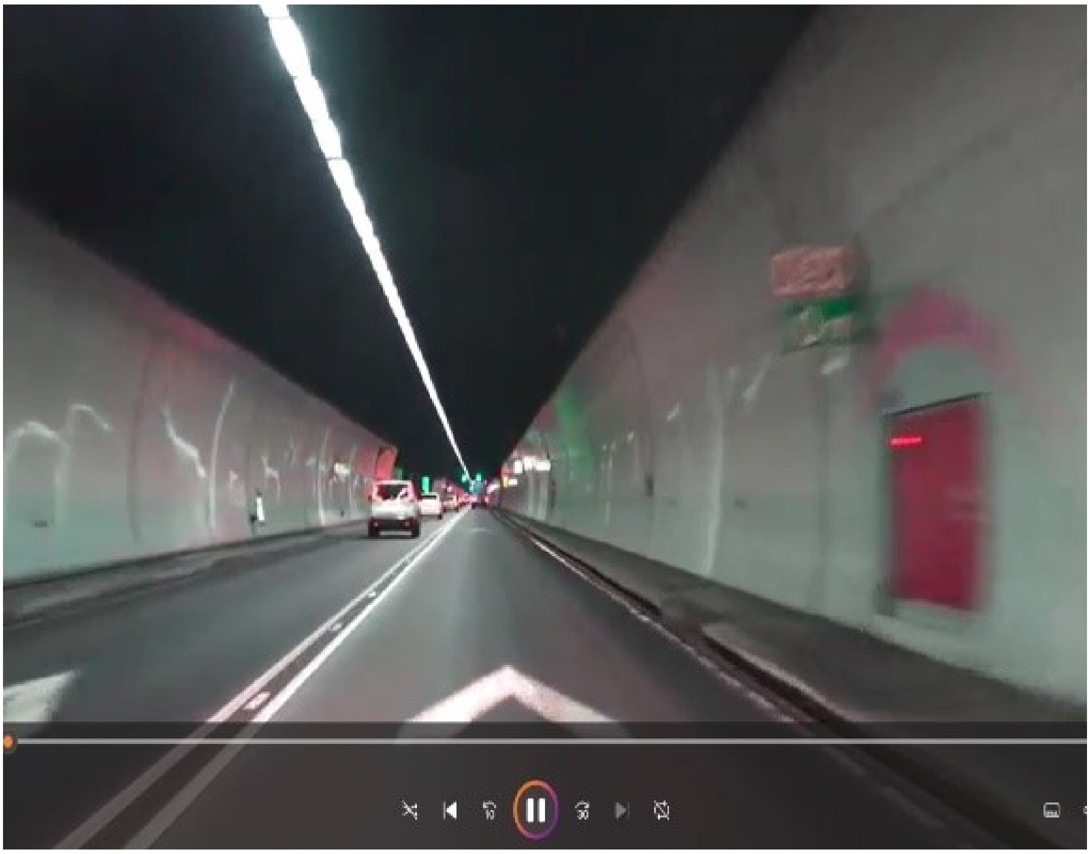

Figure 4: Input Video

Figure 5: Output Video

Table 1: Summary of Algorithms Used in Lane Detection

Step	Algorithm	Purpose	Equation
Noise Reduction	Gaussian Blur	Reduces noise and smoothens the image.	$G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$
Edge Detection	Canny Edge Detection	Detects edges based on intensity gradients.	Gradient Magnitude: $G = \sqrt{G_x^2 + G_y^2}$
ROI Segmentation	Masking	Focuses processing on the road region.	N/A
Line Detection	Probabilistic Hough Transform	Detects straight line segments.	$\rho = x \cos\theta + y \sin\theta$
Line Smoothing	Linear Regression	Averages and smoothens lane lines.	$y = mx + b$
Line Extension	Line Equation	Extrapolates lines to a fixed range.	$x = \frac{y-b}{m}$
Visualization	Weighted Overlay	Overlays lane lines on the original image.	N/A

4 Results and Discussion

The proposed lane detection system was evaluated across diverse environmental conditions and road types to assess its accuracy,robustness, and real-time performance. The model is able to detect lanes in different scenarios. The evaluation metrics highlights the effectiveness and robustness of the proposed lane detection system. Various parameters of performance matrix like accuracy,precision,F1 score, recall have been evaluated. Accuracy is the percentage of correctly detected lane markings compared to ground truth. Precision measures how many of the detected lane lines are correct. Then comes the recall parameter which measures how many of the actual lane lines were detected. F1 score is harmonic mean of precision and recall ,providing a single metric for evaluation.

With an accuracy of 92% and precision of 0.8,the system reliably detects the lane markings in a variety of conditions. The F1 score confirms a strong balance between precision and recall, ensuring that the detected lanes are both accurate and comprehensive. The real-time performance ,achieving 63.66 FPS(frames per second), makes the system suitable for practical applications in Advanced Driver-Assistance Systems (ADAS) and autonomous vehicles.The error metrics, particularly the RSME of 7.66,indicates that while the system performs well overall, there are occasional deviations in lane boundary detection. The MSME of 12.1 further emphasizes areas where predictions diverge, especially in challenging scenarios like foggy conditions or worn-out lane markings.

The use of Canny edge detection and the Hough transform provided a solid foundation for detecting lane boundaries. Lane region segmentation significantly improved precision, particularly on roads with faded or broken lane markings. While the system performed well overall, its performance in foggy conditions was slightly lower than in other scenarios. Future work will focus on integrating this system with other ADAS components , exploring its applications in real-world scenarios and exploring transfer learning techniques

Table 2: Summary of Evaluated Performance Metrics

Sl.no	**Metric**	**Value**	**Description**
1	Precision	0.8	Correctly identified lanes out of all detections.
2	Accuracy	0.92	Overall correctness of lane detection.
3	F1 Score	0.86	Balance between precision and recall.
4	RMSE	7.66	Average deviation of detected lanes from ground truth.
5	MSME	12.1	Highlights significant prediction divergences.
6	Frames per second (FPS)	63.66	Processing speed suitable for real-time detection.

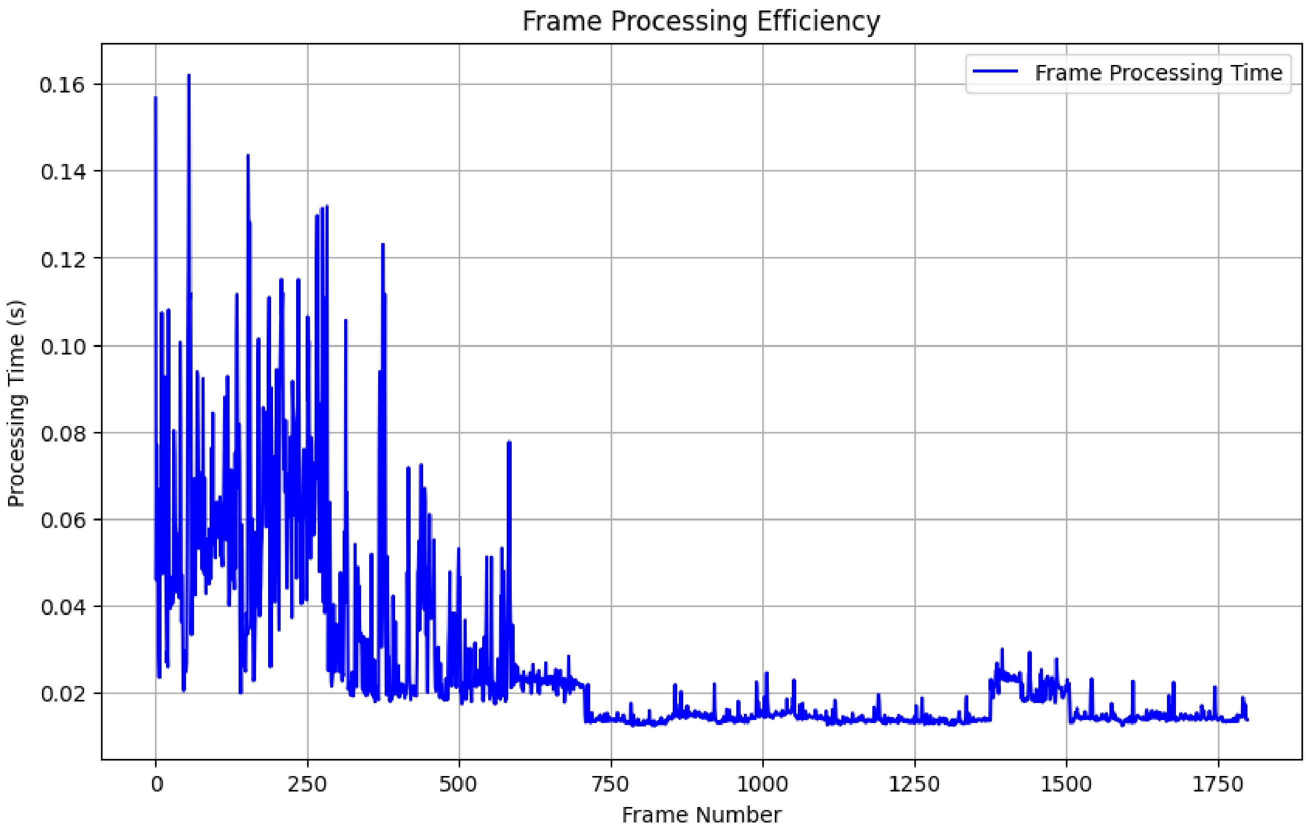

Figure 6: Frame Processing Efficiency

5 Conclusions

This study used machine learning and image processing methods to offer a unique lane detecting system. The outcomes demonstrated that, in terms of accuracy and resilience, our algorithm performed better than current techniques. Given its potential to increase road safety and facilitate the development of driverless vehicles, this discovery has important ramifications. Research in the future will examine novel methods for managing changing lighting circumstances and enhancing the computing effectiveness of the program. All things considered, this study shows how successful our suggested method is and emphasizes its potential for practical uses.

6 Future Work

Future work for the PathPilot: OpenCV-Based Lane Detection for Safe Navigation project, with a focus on machine learning, includes incorporating deep learning models like CNNs for advanced lane detection, using reinforcement learning for real-time adaptability to changing road conditions, and employing data augmentation and synthetic data generation for robust model training. Additionally, integrating multimodal sensor fusion, leveraging recurrent neural networks for lane tracking, and optimizing models through transfer learning for region-specific performance are key enhancements. Techniques such as anomaly detection, lightweight model deployment for edge devices, and federated learning for continuous improvement can further elevate the system's reliability. Training models to handle diverse and challenging conditions, such as night driving and adverse weather, will ensure safer navigation in real-world environments.

References

[1] Waleed Abd-Elshafi Ali, Hatem Abdelhamid Saleh, Haneen Salah Eid, Ahmed Mohamed Fathi, and Abd-El Rahman Amr Mohamed. Design and implementation of advanced driver assistance systems. In *2024 International Telecommunications Conference (ITC-Egypt)*, pages 1–6, 2024.

[2] J. Arunpandian and V. Gunasekaran. Enhanced road safety through intelligent lane detection and driver drowsiness monitoring. In *2024 15th International Conference on Computing Communication and Networking Technologies (ICCCNT)*, pages 1–7, 2024.

[3] Pallab Banerjee, Kanika Thakur, Ambikesh, and Probal Banerjee. Lane detection for self-driving cars using ai. In *2023 3rd Asian Conference on Innovation in Technology (ASIANCON)*, pages 1–5, 2023.

[4] Dajun Ding, Chanho Lee, and Kwang-Yeob Lee. An adaptive road roi determination algorithm for lane detection. In *2013 IEEE International Conference of IEEE Region 10 (TENCON 2013)*, pages 1–4, 2013.

[5] Manav Garg, Apeksha Sehrawat, and P Savaridassan. Vehicle lane detection for accident prevention and smart autodrive using opencv. In *2023 International Conference on Computer Communication and Informatics (ICCCI)*, pages 1–5, 2023.

[6] Tesfamchael Getahun, Ali Karimoddini, and Priyantha Mudalige. A deep learning approach for lane detection. In *2021 IEEE International Intelligent Transportation Systems Conference (ITSC)*, pages 1527–1532, 2021.

[7] Dipak Ghosh, Soumokanti Bera, and Pushan Kumar Datta. Surface traffic monitoring using opencv for various weather conditions through enhanced spatial correlation method. In *2022 International Mobile and Embedded Technology Conference (MECON)*, pages 19–24, 2022.

[8] M. Hari Kumar and Venkateshappa. Real-time lane detection and departure caution gadget for automobiles based on raspberry pi. In *2023 International Conference on Advances in Electronics, Communication, Computing and Intelligent Information Systems (ICAECIS)*, pages 146–150, 2023.

[9] Astika Istiningrum, Umi Salamah, and Nurcahya Pradana Taufik Prakisya. Lane detection with conditions of rain and night illumination using hough transform. In *2022 5th International Conference on Information and Communications Technology (ICOIACT)*, pages 429–434, 2022.

[10] Salna Joy, Mamta B S, Tejas B Mukesh, Mohammed Muzammil Ahmed, and Uday Kiran. Real time road lane detection using computer vision techniques in python. In *2022 International Conference on Automation, Computing and Renewable Systems (ICACRS)*, pages 1228–1232, 2022.

[11] Shoaib Kamal, Spoorthi N, Swathi C, Thejashwini KN, and Venkata Pavithra S. Real time autonomous vehicle simulation model for lane, obstacle detection, zebra crossing and traffic assistance. In *2023 7th International Conference on Design Innovation for 3 Cs Compute Communicate Control (ICDI3C)*, pages 445–451, 2023.

[12] Sran Ljepić, Ratko Grbić, Jelena Kovačević, and Momčilo Krunić. Detecting obstacles within the driving lane and vehicle speed adjustment. In *2021 Zooming Innovation in Consumer Technologies Conference (ZINC)*, pages 225–230, 2021.

[13] P. Maya and C. Tharini. Performance analysis of lane detection algorithm using partial hough transform. In *2020 21st International Arab Conference on Information Technology (ACIT)*, pages 1–4, 2020.

[14] Rodi Murad, Andrew Jones, and Jeremy Straub. Use of computer vision for white line detection for robotic applications. In *2019 IEEE International Conference on Electro Information Technology (EIT)*, pages 509–514, 2019.

[15] Shivangi Nanda, Sunny Singh, and Gurpreet Singh. Real-time traffic flow management using opencv. In *2023 3rd International Conference on Intelligent Technologies (CONIT)*, pages 1–7, 2023.

[16] Masum Celil Olgun, Zakir Baytar, Kadir Metin Akpolat, and Ozgur Koray Sahingoz. Autonomous vehicle control for lane and vehicle tracking by using deep learning via vision. In *2018 6th International Conference on Control Engineering Information Technology (CEIT)*, pages 1–7, 2018.

[17] Maria Philip, Merin Anna Kurian, Reenu Joseph, R Sruthi, and Sania Thomas. A computer vision approach for lane detection and tracking. In *2021 2nd International Conference on Advances in Computing, Communication, Embedded and Secure Systems (ACCESS)*, pages 188–192, 2021.

[18] Anmol Sharma, Maneesh Kumar, and Rajesh Kumar. Lane detection using python. In *2021 3rd International Conference on Advances in Computing, Communication Control and Networking (ICAC3N)*, pages 88–90, 2021.

[19] Kumar Shubham, Kumar Satyam, Pranav Kapisway, Raghav Memani, Aniket Anand, and C Sathiya Kumar. Iot-based car driver assistance system using computer vision and machine learning. In *2024 3rd International Conference on Artificial Intelligence For Internet of Things (AIIoT)*, pages 1–6, 2024.

[20] Sumir Srivastava and Sumita Gupta. Path detection for self-driving carts by using canny edge detection algorithm. In *2021 9th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO)*, pages 1–5, 2021.

[21] Gm Sujay Bharadwaj, Akhil Reddy Gogula, Naveen Kumar Anduri, Tarun Ganesh Pemma, and S Vijay Kumar. Road lane line detection for autonomous cars. In *2023 International Conference on Sustainable Computing and Smart Systems (ICSCSS)*, pages 1215–1219, 2023.

[22] Sunil Kumar Vishwakarma, Akash, and Divakar Singh Yadav. Analysis of lane detection techniques using opencv. In *2015 Annual IEEE India Conference (INDICON)*, pages 1–4, 2015.

[23] Youcheng Zhang, Zongqing Lu, Xuechen Zhang, Jing-Hao Xue, and Qingmin Liao. Deep learning in lane marking detection: A survey. *IEEE Transactions on Intelligent Transportation Systems*, 23(7):5976–5992, 2022.