Intelligent Driver Assistance through AI-based Lane and Object Detection System

Ameyasingh Chauhan, Chirag Thawale, Pritam Bhokare, Prof. Amruta Kulkarni
G H Raisoni College of Engineering and Management, Pune Department of Ai & AIML

Abstract: Drivers rely on visual cues for navigation, with road lines serving as constant guides for steering. A key objective of smart-driving vehicles is to automatically detect these lane lines using algorithms. Lane detection, however, remains a complex challenge that has captivated the computer vision community for many years. It is a multi-feature detection problem that both computer vision and machine learning algorithms continue to address with limited effectiveness. We present an image processing method based on the Hough Transform, Canny Edge Detection, and Object Detection. The primary objective is to utilize the Canny edge detection algorithm to identify features, followed by a method to detect lane lines in images or video. Given the inherent imperfections in images, determining the slope and intercept of lines by examining individual pixels presents significant complexity. The Hough Transform is employed to address this challenge, as it facilitates the identification of significant lines and connects discontinuous edge points within an image. Furthermore, Object Detection is implemented to identify vehicles in proximity to the detected lanes.

Keywords: Hough Transform, Canny Edge Detection, Object Detection, Feature Detection

I. INTRODUCTION

Recently, computer vision and machine learning have revolutionized the technology concerning road safety and significantly enhanced the development of systems for intelligent driver assistance and highly sophisticated self-driving vehicles. Such systems depend mainly on real-time detection of major road features like lanes, curves, and obstacles to make driving more efficient and safer. Among the most common techniques used for lane detection and curve detection is that of Canny edge detection and Hough transform algorithms, which help in accurately locating road markings. These techniques are very important because they will provide an understanding of the surroundings to an autonomous vehicle, or even to a human driver in trying conditions.

The other essential part of a driver assistance system is object detection. Due to the current practices in deep learning models, such as YOLO (You Only Look Once), vehicles, pedestrians, and more road objects are now being correctly detected. YOLO, due to the real-time object detection at high precision, is the first choice for lots of applications in the automotive industry. The systems are capable of providing situational awareness to the drivers by embedding lane, curve, and object detection altogether. These may help protect them from hazards encountered along the road while driving.

The paper is going to review the significant algorithms and methods carried out within lane detection, curve detection, and object detection, especially with respect to their application within driver assistant and autonomous driving systems. It discusses the efficiency of Canny edge detection and Hough transform for the detection of roads and curvatures as well as examines the role of YOLO in object detection. Finally, this review draws attention to the combination of techniques in order to make the functionality and reliability of modern road safety solutions even greater.

II. LITERATURE SURVEY

The detection of lanes and objects is crucial to ensuring safer roads and continued advancement of self-driving cars. Traditional methods for lane detection rely heavily on image processing techniques like the Canny edge detection and Hough Transform, which work relatively well under mostly ideal conditions for lane marking identification. "Zhang, Y., Liu, Z., & Jiang, L. (2018). Robust lane detection for autonomous driving. IEEE Transactions on Intelligent Transportation Systems", demonstrated that such methods can perform quite well but generally struggle with bad weather or low lighting.

The development of deep learning has transformed the object detection landscape of methods like YOLO, which stands for You Only Look Once. Redmon, J., Divvala, S., Girshick, R., & Farhadi, A. (2016). "You only look once: Unified, real-time object detection. Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition", proposed it can detect several objects in one pass and is, therefore, very much useful for applications that need swift responses, as the cases of self-driving cars are. Better designs characterize the later versions, such as YOLOv8.

Most recent research focuses on integrating lane and object detection. Kim, D., & Kim, H. (2020). "A unified lane and object detection framework for autonomous driving." IEEE Access, proposed a framework that could simultaneously detect lanes and vehicles, thereby giving a comprehensive view of the road to self-driving systems. The integration gives the impression that the worth of the use of both conventional and advanced techniques may be the solution to the challenges presented in different driving scenarios.

Although these systems have so many progresses, challenges and lack of visibility are some of the issues that need to be improved. Future research should focus on improving the reliability of such systems through data augmentation techniques, transfer learning, and information fusion from one sensor to ensure that the systems really work seamlessly under real-life scenarios.

III. METHODOLOGY

The aim of this project is to develop an integrated system for the automatic detection of road lanes, curves, and vehicles, which can assist drivers or be used in driverless vehicles. The system consists of two significant components: lane and curve detection using the Canny edge detection technique, and object detection using the YOLO deep learning model. This section explains the step-by-step methodology for implementing these two components and integrating them into a real-time road safety system.

1. Lane and Curve Detection

1.1. Preprocessing the Input

Preprocessing of the input video or image frames is the first step in lane detection. Typically, raw frames captured from the camera contain noise and unwanted features that hinder accurate lane detection. Therefore, the input image is initially converted to grayscale to reduce computational complexity and eliminate color information that is irrelevant for edge detection. Following this, a Gaussian blur is applied to smooth the image, reduce noise, and preserve meaningful edges.

1.2. Canny Edge Detection

After pre-processing of the image, it employs the Canny edge detection algorithm to detect the strong edges necessary for lane detection. This includes detecting where intensity changes sharply, usually lanes - the gradients are analyzed in the case of an image and, hence, it reduces noise and computes gradients so that non-maximum suppression can be applied, retaining only the most important edges.

1.3. Region of Interest (ROI) Selection

Certain parts of the image are irrelevant for lane detection. Therefore, a region of interest (ROI) is typically selected in the bottom half of the image, as this area contains the lanes. By focusing only on this relevant portion of the frame, the processing of unnecessary areas is minimized, reducing the potential for errors.

1.4. Hough Transform for Lane Detection

The system employs the Hough Transform to detect lane lines. It identifies all straight lines from the edge points and converts these into a format that facilitates easier identification of lines. Even when lane lines are dashed or obscured, detection continues by establishing a threshold for the minimum number of points that need to align. The detected lane lines are then overlaid on the original image.

2. Object Detection Using YOLO

2.1. Object Detection Model

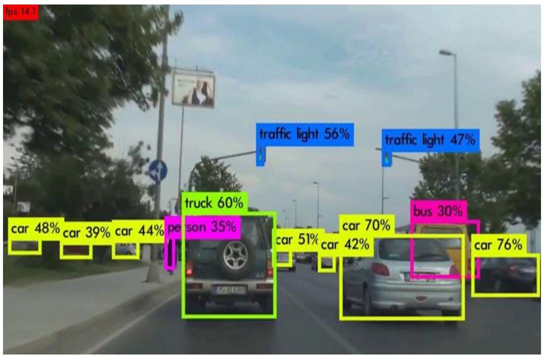
The second important component of the system addresses object detection. Considering the identification of vehicles, such as cars, trucks, or buses, the YOLO (You Only Look Once) algorithm is used since it ensures processing of the task. YOLO takes up the image in a grid-based form where it predicts bounding boxes and class probabilities for all the grid cells. This enables YOLO to detect several objects simultaneously, making it ideal for use in road settings, where there may be more than one vehicle of interest.

2.2. Model Training and Pretrained Weights

The YOLO model is normally pre-trained on large datasets with annotated images of various objects. In this project, the pre-trained YOLO was fine-tuned in order to highlight exactly road objects, like cars, buses, and trucks. The use of pre-trained weights makes this model possible to identify objects in video frames without requiring much additional training.

2.3. Bounding Box Prediction

As the YOLO model is applied to each frame, it predicts bounding boxes around objects along with their class labels, such as “car” or “truck” and their associated confidence scores. These bounding boxes are displayed on the output frame, providing real-time information that the driver or an autonomous system can use to monitor surrounding vehicles. The bounding boxes also allow the system to track the locations and movements of other vehicles, enabling it to effectively monitor traffic conditions.



3. Integration of Lane Detection and Object Detection

3.1. Combining Lane Detection and YOLO Outputs

In the final step, outputs from lane detection and object detection are combined. The bounding boxes generated by YOLO for the objects are superimposed on the original image along with the outputs of Canny edge detection and Hough transform used to detect lanes. Thus, both are overlaid together on the original image to give an impressive view of the road. Lanes that the car is to follow and objects, such as vehicles, to be avoided are depicted.

4. System Evaluation

4.1. Testing on Various Road Conditions

The system is tested with videos from a variety of road conditions, such as highways, urban streets, and curved roads, to test the performance of the lane detection system regarding accurate lane detection irrespective of surface conditions. On another hand, object detection based on YOLO is tested for accuracy and response time, especially in cases of detecting vehicles.

4.2. Performance Metrics

Some of the key performance metrics for the system include accuracy, recall, and fps: Precision and recall both assess how well the lane and object detection modules are working, and fps relate to real-time video processing capabilities for the system. Besides, qualitative assessments of the state of the overall vision system are performed by visual inspection of the overlays produced over the test videos.

IV. CONCLUSION/FUTURE SCOPE

This review highlights the integration of lane and curve detection using the Canny Edge Detection technique, combined with the Hough Transform, alongside object detection using YOLO, to enhance road safety. The proposed system can accurately identify road lanes and curves, detect moving vehicles, and assist drivers or control autonomous vehicles to maintain lane discipline and avoid potential hazards.

The Canny Edge Detection filter effectively reduces noise, leaving only essential lane features, while the Hough Transform identifies all two-line structures, whether straight or curved. The inclusion of YOLO for fast detection and tracking of surrounding objects adds an extra layer of safety to the system. Together, these methods provide a robust foundation for advanced driver assistance systems and autonomous driving technologies.

Future improvements could increase the system's efficiency in adverse weather conditions, enable additional functionalities such as road sign recognition, and facilitate communication with other vehicles.

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