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Real-Time Vehicle Detection and Lane Tracking System using Advanced Computer Vision Techniques

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Abstract: This project introduces a Real-Time Vehicle Detection and Lane Tracking System aimed at improving traffic monitoring and road safety through advanced computer vision and deep learning. Using the YOLOv8 model, the system detects multiple vehicle classes in live video streams and assigns unique IDs through multi-object tracking. Lane boundaries are extracted using edge detection and region masking, enabling accurate lane classification for each vehicle. The system also identifies lane-crossing events and automatically logs them into a structured CSV file for further analysis. Additionally, the system estimates vehicle speed, tracks movement patterns, and generates activity logs using pixel displacement and frame-based analysis. A real-time Streamlit dashboard visualizes detections, lane overlays, and tracking information to provide a clear overview of road activity. With its modular and efficient design, the solution supports applications in smart traffic management, violation detection, and intelligent transportation systems, offering a scalable and accurate approach for real-time roadway surveillance.
Keywords: Real-Time Vehicle Detection, Lane Tracking, YOLOv8, Computer Vision, Intelligent Transportation System.

I. INTRODUCTION

Traffic congestion and road safety are major challenges in modern transportation systems, requiring accurate and real-time information about vehicle movement, lane usage, and traffic density. Traditional monitoring methods depend on manual observation or costly sensor-based systems, which are often inefficient and lack scalability. To overcome these limitations, the project *"Real-Time Vehicle Detection and Lane Tracking System using Advanced Computer Vision Techniques"* proposes an intelligent, automated solution that leverages deep learning and computer vision for effective traffic monitoring.

The system uses the YOLOv8 (You Only Look Once) object detection model to identify various vehicle types—including cars, motorcycles, buses, and trucks—from video footage. Each frame is analyzed using the OpenCV library to detect vehicles, assign unique tracking IDs, and monitor their movement across frames. Lane tracking is performed by dividing the road into predefined lanes and identifying the lane of each detected vehicle, including lane-change events that indicate driving behavior and traffic flow. Additional features include vehicle speed estimation, lane-wise vehicle counting, and real-time traffic density classification. All results, such as bounding boxes, lane numbers, and speed details, are displayed visually on the processed video. A Streamlit-based interface allows users to upload and analyze traffic videos interactively, while downloadable CSV logs provide structured data on vehicle activity for further analysis. The primary goal of this project is to demonstrate how advanced computer vision and deep learning techniques can be applied to build an intelligent and fully automated traffic monitoring system. By providing real-time vehicle detection, lane analysis, speed estimation, and traffic density evaluation, the system supports improved traffic management, enhances road safety, and contributes to the development of smart city infrastructure.

II. LITERATURE REVIEW

Traditional traffic monitoring systems relied on manual observation and sensor-based methods, which were often costly, less scalable, and inaccurate in complex environments. Early computer vision techniques such as background subtraction, optical flow, and edge detection were used for vehicle detection, but they struggled with occlusions, lighting variations, and high traffic density.

With the advancement of deep learning, models like Faster R-CNN, SSD, and especially YOLO significantly improved real-time object detection performance.

YOLOv8 offers high accuracy and speed, making it suitable for detecting multiple vehicle types in live video feeds. Multi-object tracking approaches such as SORT and Deep SORT further enhanced vehicle tracking by maintaining unique IDs across frames.

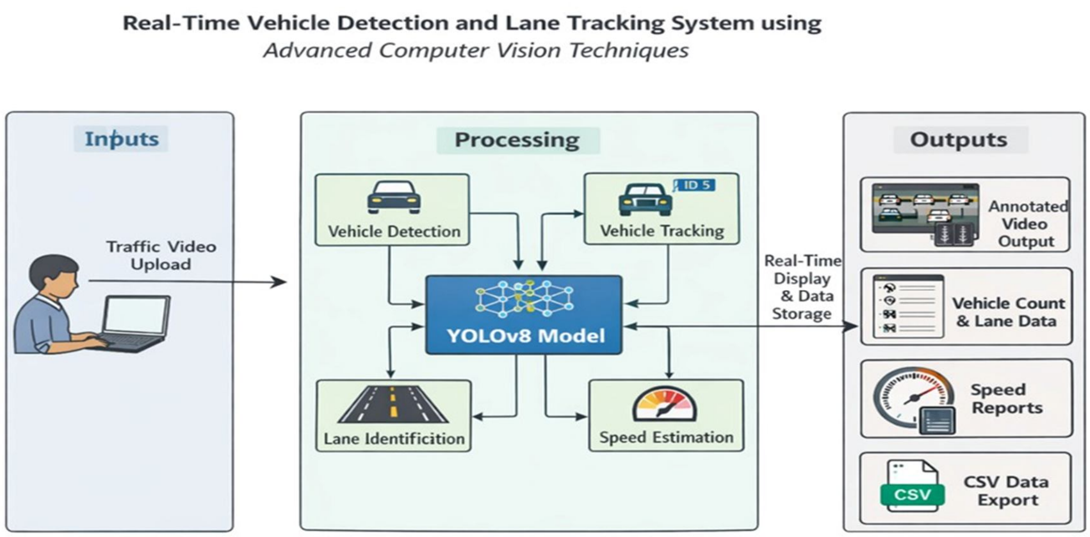
Lane detection techniques evolved from traditional Hough Transform methods to deep learning–based segmentation models, making lane detection more reliable in different road conditions. Studies also highlighted the importance of integrating vehicle detection, tracking, speed estimation, and lane analysis into a single system to support smart traffic management.

Overall, recent research shows that combining deep learning with computer vision provides a highly effective approach for automated, real-time traffic monitoring and intelligent transportation systems.

III. PROBLEM STATEMENT

Modern traffic systems face challenges such as congestion, unsafe lane changes, and inefficient monitoring due to the limitations of manual observation and traditional sensor-based methods. These existing approaches often fail to provide accurate, real-time information about vehicle movement, lane usage, speed, and traffic density. There is a need for an automated, scalable, and intelligent system capable of detecting vehicles, tracking their motion, identifying lane changes, and analyzing traffic conditions in real time. This project aims to address these challenges by developing a computer vision–based solution that integrates deep learning techniques for reliable vehicle detection, lane tracking, and traffic analysis.

IV. SYSTEM ARCHITECTURE



V. METHODOLOGY

The system processes traffic video input using the YOLOv8 model to detect multiple types of vehicles in real time. A tracking algorithm assigns unique IDs and follows vehicle movement across frames. Lane boundaries are identified using image processing, allowing each vehicle to be classified into the correct lane. The system then detects lane-change events and estimates vehicle speed based on positional changes. All results—including detections, lane overlays, and statistics—are visualized through a Streamlit interface, while traffic data is saved in CSV format for further analysis.

VI. ADVANTAGES

1) Provides real-time and accurate vehicle detection using YOLOv8.
2) Automatically tracks vehicles and identifies lane changes.
3) Cost-effective solution using regular cameras instead of expensive sensors.
4) Generates useful traffic data like speed, counts, and density.
5) Offers a simple and interactive Streamlit interface for easy analysis.

VII. LIMITATIONS

1) Performance may decrease in poor lighting, rain, fog, or low-quality video.
2) Accuracy depends on correct camera angle and stable video input.
3) Lane detection may fail on roads with faded or unclear lane markings.
4) High-computation models like YOLOv8 require good hardware for real-time processing.
5) Speed estimation may be less accurate without proper camera calibration.

VIII. FUTURE SCOPE

1) Integration with IoT sensors and smart traffic lights for automated traffic control.
2) Implementation of advanced lane segmentation using deep neural networks for higher accuracy.
3) Addition of accident detection, wrong-way driving alerts, and driver behavior analysis.
4) Deployment on edge devices like NVIDIA Jetson for real-time on-road processing.
5) Expansion into city-wide monitoring systems using cloud-based analytics and dashboards.

IX. CONCLUSION

The Real-Time Vehicle Detection and Lane Tracking System using Advanced Computer Vision Techniques was successfully developed to analyze traffic videos in an efficient and practical manner. The system is capable of detecting vehicles, tracking their movement, assigning them to different lanes, identifying lane changes, estimating speed, and calculating traffic density. By using YOLOv8, OpenCV, Python, and Streamlit, the project provides an effective solution for intelligent traffic monitoring and analysis.

The developed system improves the accuracy and speed of traffic observation when compared to manual monitoring methods. It reduces human effort, provides continuous analysis, and generates useful output such as annotated video frames and CSV logs for further study. The project also demonstrates that advanced computer vision techniques can be applied successfully in real-time traffic applications with good reliability and performance.

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