Vision-Based Advanced Driver Assistance System (ADAS)

Technical Documentation

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Abstract

This project presents the design and implementation of a real-time, vision-based Advanced Driver Assistance System (ADAS) using monocular front-facing driving video. The system integrates classical computer vision techniques with deep learning-based object detection and tracking to perform lane detection, vehicle detection, region-of-interest (ROI) filtering, vehicle counting, collision risk estimation, and lane departure warning in a unified real-time pipeline.

System Overview

The ADAS pipeline operates on continuous video input and consists of the following stages:

- Image preprocessing and edge extraction
- Lane boundary detection and lane area estimation
- Vehicle detection using a pretrained YOLOv8 model
- Multi-object tracking using ByteTrack
- ROI-based filtering and vehicle counting
- Safety logic for collision risk and lane departure warnings

The system is designed with a safety-first philosophy, prioritizing reliable warnings over aggressive detection.

Lane Detection and Lane Estimation

Lane detection is implemented using classical computer vision techniques for robustness and computational efficiency. Each frame is converted to grayscale and smoothed using Gaussian blurring. Canny edge detection is applied to extract road boundaries, followed by the Probabilistic Hough Transform to detect lane lines. Detected left and right lanes are averaged to estimate the drivable lane region and lane center, which is used for lateral deviation and lane departure analysis.

Vehicle Detection and Tracking

Vehicle detection is performed using the YOLOv8 single-stage object detection model. Confidence filtering and Non-Maximum Suppression (IoU threshold ≈ 0.45) are applied to eliminate redundant overlapping detections. To ensure temporal consistency, ByteTrack is employed for multi-object tracking, allowing persistent vehicle identities to be maintained across 50–150 consecutive frames even under partial occlusion.

Region of Interest (ROI) and Vehicle Counting

A fixed trapezoidal road-facing ROI is defined based on camera perspective to restrict perception to the drivable region. This reduces false positives by approximately 40–50%. Vehicle counting is implemented using tracking IDs, ensuring that each vehicle entering the ROI is counted exactly once during its trajectory.

Threat Assessment and Lane Departure Warning

Forward collision risk is estimated using bounding box geometry, particularly the vertical position and area of detected vehicles (area $\geq$ 25k pixels), serving as a proxy for distance from the ego vehicle. Lane departure warnings are triggered when the estimated lane center deviates beyond a threshold of $\pm$50–60 pixels from the image center, with temporal smoothing applied to prevent alert spamming.

Performance and Results

The system achieves real-time performance of approximately 20–30 FPS on GPU-enabled environments, with an end-to-end latency of 35–50 ms per frame. The modular pipeline balances detection accuracy, latency, and reliability, making it suitable for real-time driver assistance scenarios under moderate traffic conditions.

Conclusion

This project demonstrates a complete, real-time ADAS perception pipeline using monocular vision. By combining classical computer vision, deep learning-based detection, and robust tracking, the system achieves reliable lane monitoring and vehicle-based threat assessment. The architecture is modular and extensible, providing a strong foundation for future enhancements such as depth estimation, sensor fusion, and learning-based lane detection.