Traffic Speed Detection and Tracking in Harsh Weather Conditions via YOLO

Abstract

This research presents a comprehensive evaluation of vehicle detection and speed estimation systems under adverse weather conditions using YOLOv11 architecture. A systematic framework was developed to assess performance across six distinct environmental scenarios: clear day, clear night, foggy day, foggy night, rainy day, and rainy night. The study employs synthetic weather generation techniques combined with real-world GPS coordinate calibration from Prague D1 highway to create controlled evaluation conditions while maintaining practical relevance. The methodology integrates YOLOv11 object detection with ByteTrack multi-object tracking and perspective transformation-based speed estimation. Synthetic weather conditions were generated through parametric image processing techniques, enabling reproducible comparative analysis across environmental scenarios. Real-world coordinate mapping using GPS coordinates ensures accurate speed calculation through validated perspective transformation matrices. Experimental results demonstrate robust system performance across all weather conditions, with processing frame rates maintained between 8.7 and 10.4 FPS and speed estimation consistency within 4.3 km/h variation across extreme conditions. The system successfully processed 218 vehicles with an average speed estimation of 110.8 km/h, validating the effectiveness of computer vision approaches for traffic monitoring applications. Weather-specific behavioral patterns were quantified, revealing distinct driver adaptation strategies across environmental conditions. The research provides evidence-based performance benchmarks that support deployment decisions for vision-based traffic monitoring systems, addressing critical gaps in weather robustness evaluation for intelligent transportation applications.

Keywords: Vehicle Detection, Speed Estimation, YOLOv11, Weather Robustness, Traffic Monitoring, Synthetic Data Generation, Multi-Object Tracking, Intelligent Transportation Systems