Research on Algorithms of Computer Vision for Safety Motion Control of Self-Driving Cars

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Introduction. The rapid advancement of urbanization and the growing number of vehicles on roads have made traffic management and road safety a critical concern for modern societies. Traffic congestion, road infrastructure deterioration, and human errors contribute significantly to accidents, injuries, and fatalities worldwide. According to traffic safety reports, human-related factors such as fatigue, distraction, and drowsiness account for approximately 80% of road accidents [1], [2]. These alarming statistics highlight the urgent need for intelligent transportation systems (ITS) that leverage advanced technologies to enhance road safety and improve overall traffic efficiency.

Deep learning has revolutionized the field of object detection, enabling the development of real-time, high-performance models capable of recognizing complex patterns in images and videos [3]. The introduction of single-stage and transformer-based object detection architectures, such as Real-Time Detection Transformer (RT-DETR), and You Only Look Once (YOLO) has significantly improved the speed and accuracy of detection tasks in autonomous driving applications [4], [5]. These models are capable of processing vast amounts of visual data in real time, allowing autonomous systems to respond swiftly to potential hazards and make informed driving decisions.

Main Part. In this study, we propose an integrated traffic environment detection system utilizing state-of-the-art deep learning models, specifically RT-DETR, YOLOv8, and YOLOv11, to detect and classify essential traffic elements. The system is trained using diverse datasets, including the Russian traffic sign dataset, the Udacity self-driving car dataset, and datasets for pothole and speed bump detection. The primary objective is to enhance the perception capabilities of autonomous vehicles and intelligent traffic monitoring systems by providing real-time detection and classification of road elements.

To further optimize the system's performance, we employ hyperparameter tuning, data augmentation techniques, and TensorRT acceleration, which significantly improve detection speed while maintaining high accuracy. The training is conducted using Google Colab Pro, and the PyTorch deep learning framework. The datasets are obtained from Roboflow, a popular computer vision platform that offers efficient methods for data collection, preprocessing, and model training. The model is trained with different numbers of epochs and hyperparameters, and detection speed is improved using TensorRT.

Conclusions. This research highlights the effectiveness of deep learning-based object detection in enhancing the safety of self-driving cars. By utilizing advanced algorithms like YOLO and RT-DETR, optimized with hyperparameter tuning and TensorRT acceleration, the system enhances road safety, minimizes accidents, and contributes to safer and more efficient autonomous navigation.

References

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