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VEHICLE SPEED MONITORING SYSTEM

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Abstract: This project develops a real-time Vehicle Speed Monitoring System utilizing machine learning and camera-based vision techniques to provide an efficient and cost-effective alternative to traditional speed detection systems. The system uses only a standard video camera and Python-based software to continuously monitor traffic flow. Vehicles are detected through deep learning object detection models, and their movement is tracked frame-by-frame using computer vision tracking algorithms. By computing pixel displacement over time and converting it into actual distance through calibration, the system accurately estimates vehicle speeds. Overspeeding events trigger automatic alerts, frame capture, and data logging. Eliminating the need for physical sensors significantly reduces installation and maintenance costs while increasing flexibility and scalability. The system is suitable for deployment in highways, intersections, school zones, and smart city infrastructures, providing a robust solution for enhancing road safety and supporting automated traffic law enforcement.

Index Terms - Vehicle Speed Estimation, Computer Vision, Machine Learning, Traffic Monitoring, Intelligent Transportation Systems

I. Introduction

This project presents a camera-based Vehicle Speed Monitoring System developed in Python, leveraging machine learning algorithms and computer vision techniques to detect, track, and compute the speed of moving vehicles in real time. The system captures a live video feed, identifies vehicles within each frame, and tracks their motion across consecutive frames using object detection and tracking models such as YOLO, Haar Cascade, or deep learning-based CNN frameworks. By calculating the displacement of a vehicle within a calibrated scene and analyzing frame-rate information, the system computes the real-world speed of each detected vehicle. When a vehicle exceeds the predefined speed limit, the system can issue alerts, log the violation, or store an image/video snippet as evidence.

II. Literature Review

Vehicle speed monitoring has traditionally relied on sensor-based technologies such as radar, LIDAR, and inductive loop detectors, which offer high accuracy but involve significant installation and maintenance costs. To overcome these limitations, research has increasingly focused on vision-based speed estimation using traffic surveillance cameras. Early approaches employed classical image processing techniques, including background subtraction and optical flow, for vehicle detection and tracking; however, these methods were sensitive to illumination changes and occlusions. Recent advances in deep learning have significantly improved performance through the use of object detection models such as YOLO, SSD, and Faster R-CNN, combined with multi-object tracking algorithms like SORT and DeepSORT. Speed estimation is commonly achieved by analyzing pixel displacement across consecutive frames and mapping it to real-world distance using camera calibration and geometric models. Several studies report high accuracy and real-time performance without the need for physical sensors, making vision-based systems cost-effective and scalable. Despite these advancements, challenges related to camera calibration, environmental variability, and dataset availability remain active research areas.

III. Proposed System

. The proposed system implements a camera-based Vehicle Speed Monitoring System using machine learning and computer vision techniques to estimate vehicle speed in real time. The system relies solely on video input from a fixed camera, eliminating the need for traditional hardware sensors such as radar or LIDAR. Vehicles are detected using a deep learning–based YOLO object detection model and tracked across consecutive frames using the SORT tracking algorithm to maintain unique vehicle identities. Vehicle speed is calculated by measuring pixel displacement over time and converting it to real-world distance through scene calibration. The estimated speed is compared with predefined speed limits to identify overspeeding vehicles. Detected violations are highlighted and logged with time-stamped visual evidence. The proposed approach is cost-effective, scalable, and suitable for intelligent transportation and smart city traffic monitoring applications.

IV. System architecture

. The architecture of the proposed Vehicle Speed Monitoring System is designed as a modular and sequential processing pipeline that enables real-time vehicle detection, tracking, and speed estimation using video data. The system operates entirely through software and requires only a fixed camera as input, making it suitable for scalable deployment.

The architecture consists of the following main components:

1. Video Acquisition Module
   A fixed surveillance camera captures live or recorded traffic video at a constant frame rate. The video stream serves as the primary input to the system.

2. Pre-processing Module
   Captured frames are resized and normalized to ensure compatibility with the detection model. Noise reduction and frame synchronization are performed to improve detection accuracy and maintain real-time performance.

3. Vehicle Detection Module
   A deep learning–based YOLO object detection model is used to identify vehicles in each frame. The module outputs bounding box coordinates, confidence scores, and vehicle class labels.

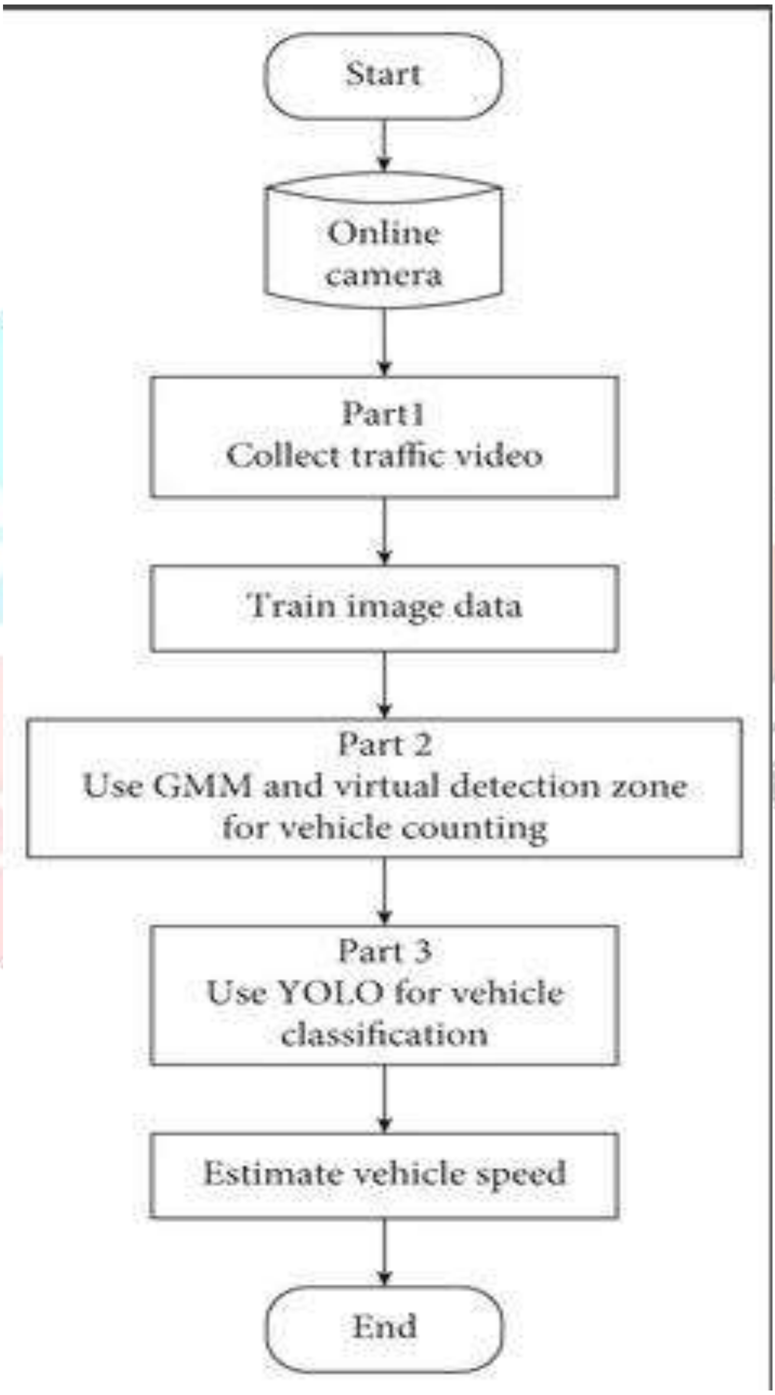
4. Vehicle Tracking Module

The SORT tracking algorithm associates detected vehicles across consecutive frames and assigns a unique ID to each vehicle. This ensures consistent trajectory tracking even in multi-vehicle scenarios.

5. Calibration and Distance Estimation Module
   Pixel displacement of tracked vehicles is converted into real-world distance using a predefined calibration factor based on known reference measurements.

6. Speed Estimation Module
   Vehicle speed is computed using distance traveled and time interval derived from the video frame rate.

7. Overspeed Detection and Logging Module
   Computed speeds are compared with predefined speed limits. Overspeeding vehicles are highlighted and violation data is logged along with visual evidence.



V. RESULT AND OUTPUT ANALYSIS

The proposed Vehicle Speed Monitoring System was evaluated using real-world traffic video sequences. The system successfully detected and tracked multiple vehicles simultaneously and estimated their speeds in real time. Experimental results show that the deep learning–based detection and tracking approach provides stable speed measurements under varying traffic conditions. Overspeeding vehicles were accurately identified and highlighted, and violation data was logged with corresponding timestamps and visual evidence. The results demonstrate reliable performance, real-time operation, and suitability for deployment in intelligent traffic monitoring applications.

VI. CONCLUSION AND FUTURE SCOPE

This project successfully demonstrates a camera-based Vehicle Speed Monitoring System using machine learning and computer vision techniques. By integrating deep learning–based vehicle detection, robust tracking, and real-time speed estimation, the proposed system provides a cost-effective and scalable alternative to traditional sensor-based speed monitoring solutions. The system enables automated overspeed detection and supports deployment using existing surveillance infrastructure.

Future Scope

- Advanced camera calibration and perspective correction
- Integration of DeepSORT for improved tracking accuracy
- Automatic License Plate Recognition (ALPR)
- Edge and GPU-based real-time deployment
- Cloud-based data storage and analytics
- Adaptation for low-light and adverse weather conditions

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