Speed Tracking and Vehicle Detection System Using Computer Vision and Web-Based Analytics

Sam Godson, Lance Rajesh Dsouza, Sonia Sandeep Lotlikar
Department of Information Technology
Fr. Conceicao Rodrigues Institute of Technology, Navi Mumbai, India

Abstract

This research is relevant to the growing problem of traffic management in rapidly expanding cities and the increasing number of vehicles. Conventional speed enforcement, including manual observation and radar technology, has been shown to have drawbacks in terms of capacity, accuracy, and reaction time. The proposed system combines computer vision technology, video processing, and web-based monitoring software to automatically locate vehicles and calculate their speed in real-time.

In particular, the system processes real-time CCTV images to locate moving vehicles, track them based on assigned identifiers, and calculate vehicle speed based on spatial-temporal distances between consecutive images. All speeding offenses and related traffic information are compiled and stored in a centralized cloud database for remote access and analysis.

The system is expected to minimize the need for human labor, improve accuracy in traffic enforcement, and facilitate data-driven decision-making for traffic managers. The system is also consistent with smart city initiatives, as it provides scalability, autonomy, and compatibility with other intelligent transportation systems.

Introduction

Road traffic safety has recently become a prominent concern owing to the growing number of privately owned vehicles and the fast pace of urbanization. Speed violations have been identified as the major cause of road accidents involving motor vehicles, leading to loss of life, damage to property, and overloading of emergency services. Conventional traffic monitoring systems are largely manual, thus less effective in high-traffic environments or large-scale road networks.

Recent breakthroughs in image processing and artificial intelligence have brought fully automated traffic monitoring systems into the limelight. These systems are capable of continuous monitoring, real-time analysis, and objective data collection with negligible human intervention. The Speed Tracking and Vehicle Detection System is one such example of the use of these technologies, which offers a robust and fully automated platform for modern traffic law enforcement.

Through the combination of computer vision algorithms and a web-based data management system, the system allows for remote traffic monitoring, real-time violation detection, and long-term traffic pattern analysis. This research aims to discuss the development and assessment of a system that aims to improve road safety, facilitate the enforcement of traffic laws, and optimize urban transportation management.

Literature Review

Recent studies have investigated image and video processing algorithms for automatic vehicle detection and speed measurement. Chandorkar et al. presented a system that uses cameras and image processing algorithms to detect vehicles and calculate their speed, proving the possibility of using cameras for monitoring. However, their system was prone to lighting changes and background noise.

Hadi et al. gave a brief summary of vehicle detection and tracking systems, emphasizing the importance of background subtraction, object tracking, and motion estimation in traffic monitoring systems. Their discussion indicated that traditional systems have cost advantages but are generally outperered by deep learning-based systems.

Other authors have designed video-based speed measurement systems as a replacement for radar guns, which have proved successful while lowering the cost of equipment.

Recent developments include deep learning-based systems such as YOLO and SSD, which provide significant improvements in detection accuracy but require large amounts of computational power and data.

The system proposed here combines the ideas of previous studies by using traditional computer vision algorithms along with real-time data analysis and cloud storage. This strategy should provide a balance between accuracy, cost-effectiveness, and scalability, making it applicable in developing countries.

System Architecture and Design

3.1 Architectural Overview

The system is designed with a modular and layered structure to allow for flexibility and easy expansion. The process starts by getting live video footage through CCTV cameras that are set up in key spots on roads or highways.

The video that's been captured is sent to the processing unit to be analyzed further.

The pre-processing module improves image quality by lowering noise, taking out background stuff, and finding the areas that are important. The vehicle detection module finds vehicles in the processed video frames by using object detection methods.

Once vehicles are detected, they are followed in each next video frame using special numbers given by the tracking system.

The speed estimation module figures out how fast a vehicle is moving by looking at how far it travels and the time it takes between frames. All the processed information, like details about vehicles and records of violations, is kept in a database that is stored in the cloud.

A web dashboard lets traffic officials see live data, create reports, and access systems from a distance. This design helps data move smoothly and keeps the system fast and ready to respond quickly.

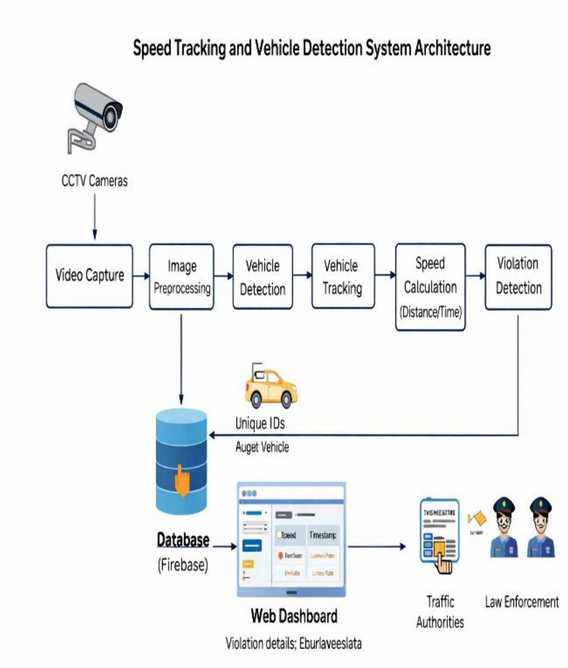

Fig 3.1

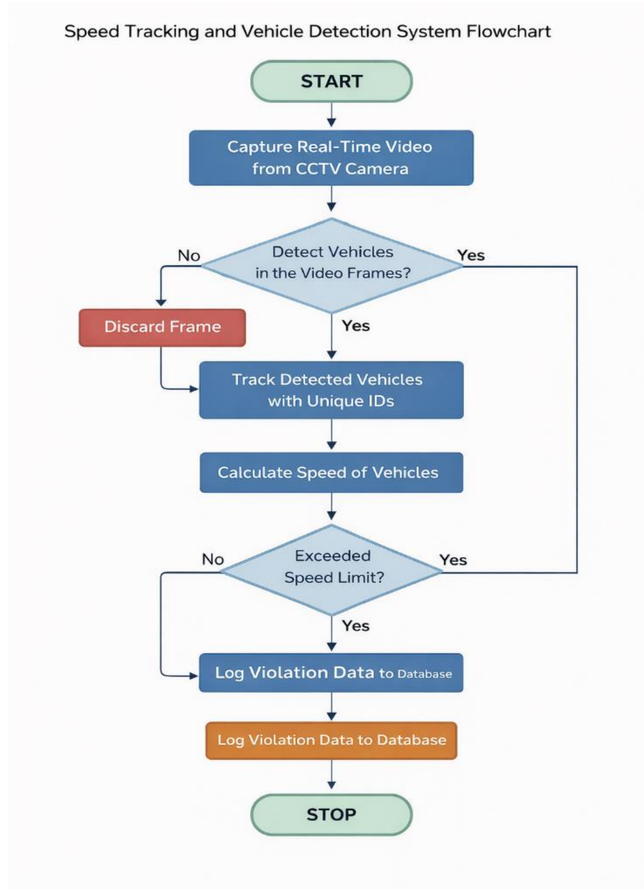

Fig 3.2

Methodology

4.1 Vehicle Detection and Tracking

The system continues to capture video frames and process them into digital images. Background subtraction is used to distinguish moving vehicles from stationary objects such as roads and buildings. This reduces the complexity of the system and increases the accuracy of vehicle detection. After detecting vehicles, the system draws a box around them and assigns a distinct identifier to each vehicle. The tracking process involves the movement of vehicles as their center points are identified and tracked from one frame to another. This is effective even in situations where multiple vehicles are moving. The process ensures consistency between frames, helps in accurate speed measurement, and helps in detecting traffic violations.

4.2 Speed Estimation

Speed estimation involves determining the distance covered by a vehicle between two distinct points in a frame sequence. Camera calibration is used to calculate the distance in real-world units, while time is calculated from the video frame rate. The speed is calculated using the formula Speed = Distance / Time. This approach does not require the use of radar or LIDAR technology, is cost-effective, and is also scalable while still offering accurate speed measurements for traffic violation checks against set speed limits.

4.3 Data Storage and Web Integration

All traffic violation information, vehicle information, time of events, and speed measurements are stored in a Firebase Realtime Database.

Results and Discussion

The test results show that the system is able to track vehicles in real time under normal lighting conditions. Moreover, when the camera is calibrated, the results of the speed estimation are accurate with a small margin of error. In contrast to manual enforcement, the system provides continuous monitoring with fewer personnel and is likely to be more reliable.

Additionally, the database system allows for easy access to the location of violation records and traffic data analysis. Nevertheless, the system is likely to be less reliable in low lighting conditions or adverse weather conditions such as heavy rain and fog.

Future Scope

The Speed Tracking and Vehicle Detection System requires persistent development because intelligent technologies keep advancing. The system would gain improved functionality through AI-based vehicle type identification which would enable it to differentiate between cars buses trucks two-wheelers and emergency vehicles. The concerned authorities would gain better speed limit enforcement capabilities through this system because it enables them to create vehicle-specific speed limits.

Deep learning algorithms that include YOLO SSD and CNN-based models would provide a major enhancement to the system. The system would gain higher vehicle detection accuracy because these models perform better in detecting vehicles during challenging situations which include low light and traffic congestion and rain and fog.

The system could gain predictive analytics capabilities which would analyze previous traffic data together with violation records to locate accident-prone areas and identify hazardous driving behaviors. The authorities will now shift their focus toward preventing accidents instead of executing post-accident corrective measures.

The system can achieve real-time traffic optimization and congestion control through its connection to smart city infrastructure which includes intelligent traffic lights and IoT sensors and command centers. The violation processing and notification system will become easier through the system's connection to e-challan websites and vehicle registration websites and mobile applications.

The system will transform into a complete intelligent transportation system which enables secure roads and effective traffic control and evidence-based decision making as technology develops throughout time.

Sr. No.	Component	Specification
1	Computer System	Minimum 8 GB RAM, 8 GB free disk space
2	CCTV Camera	HD camera with stable frame rate
3	Network Infrastructure	Stable internet connection (minimum 50 Mbps)
4	Mobile Device (Optional)	Android device with minimum 16 GB RAM, 256 GB ROM
5	Storage System	Cloud or local storage for video and logs

Sr. No.	Software	Description
1	Programming Language	Python
2	IDE	Visual Studio Code
3	Computer Vision Library	OpenCV
4	Backend Service	Firebase (Authentication, Database, Storage)
5	Database	Firebase Realtime Database (NoSQL)
6	Front-End	Python GUI (Tkinter / PyQt)
7	Version Control	GitHub

Module Name	Function
Video Capture Module	Captures real-time traffic video using CCTV cameras
Pre-processing Module	Enhances image quality and removes background noise
Vehicle Detection Module	Detects vehicles from video frames
Vehicle Tracking Module	Assigns unique IDs and tracks vehicles
Speed Estimation Module	Calculates speed using distance and time
Violation Detection Module	Identifies over-speeding vehicles
Database Module	Stores vehicle and violation data
Web Dashboard	Displays live traffic data and reports

Conclusion

The research develops a system which tracks vehicle speed while detecting vehicles to support contemporary traffic monitoring needs. The system uses computer vision and real-time analytics together with web-based data management to solve multiple issues which traditional speed enforcement methods face.

The automated systems which identify and monitor vehicles help reduce human errors while ensuring consistent and accurate traffic rule enforcement. The system enables fast detection of speeding vehicles which helps improve road safety.

The system provides a flexible design which works with cloud services to support smart city applications. The system provides a foundational framework which supports smart transportation systems and future traffic management innovations.

References

1. Mohit Chandorkar et al., *Vehicle Detection and Speed Tracking*
2. Raad Ahmed Hadi et al., *Vehicle Detection and Tracking Techniques: A Concise Review*
3. Genyuan Cheng et al., *Real-Time Detection of Vehicle Speed Based on Video Image*
4. Pranith Kumar Thadagoppula et al., *Speed Detection Using Image Processing*
5. GitHub Repositories on Vehicle Speed Estimation