

# An AI-Based Traffic Violation Detection System Using Computer Vision

Lalitha Sriya\*, Shanthi Makka

Vardhaman College of Engineering, Kacharam, Telangana

## ABSTRACT

This system presents a Traffic Violation Detection System designed to automatically identify common road rule violations using image and video processing techniques. The system analyses traffic footage to detect vehicles, track their movement, and observe their behavior at key points such as junctions and pedestrian crossings. Based on predefined rules, the system can recognize violations such as signal jumping, wrong-lane driving, over-speeding, and failure to follow road markings. Once a violation is detected, the system captures the relevant evidence frame and extracts the vehicle's number plate for record-keeping. The collected information is then stored for further review or enforcement actions. The proposed system reduces the need for continuous manual monitoring, provides consistent detection accuracy, and supports improved traffic management and road safety.

**Keywords:** Traffic, Violation, Detection, Over-speeding, Monitoring, Record-keeping.

## INTRODUCTION

Traffic management has become a major challenge in growing urban areas, where an increasing number of vehicles leads to congestion, accidents, and frequent road rule violations. Manual monitoring methods, such as traffic police and CCTV surveillance, are often time-consuming, prone to human error, and difficult to maintain across all road intersections. As a result, many violations go unnoticed, affecting road safety and overall transport efficiency. To address these limitations, automated traffic monitoring systems have become essential. These systems use image and video processing techniques to observe vehicle movement, identify unusual patterns, and detect actions that violate traffic regulations. Automating this process ensures continuous monitoring, quick response, and reliable documentation of violations such as red-light jumping, over speeding, lane indiscipline, and helmet absence. The Traffic Violation Detection System developed aims to provide an efficient solution by analyzing traffic footage and generating accurate violation reports. With automatic number plate extraction, evidence collection, and rule-based detection, the system reduces the dependence on

manual supervision and supports smarter, safer, and more disciplined road environments.

In recent years, the adoption of intelligent transportation systems has gained importance due to the increasing demand for safer and more efficient road networks. Automated traffic analysis helps authorities monitor violations continuously without physical presence at every location. This approach not only improves enforcement efficiency but also promotes disciplined driving habits and reduces accident risks.

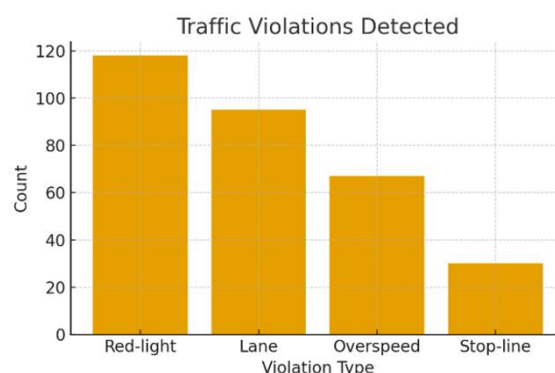


Fig. 1. Graph-based Dataset

## LITERATURE SURVEY

**Relevant conflicts of interest/financial disclosures:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

With automated monitoring of road activity has been widely studied as an approach to improve traffic regulation and reduce violations. Early works focused on identifying vehicle presence, movement patterns, and road behavior through traditional video and image processing. Jain and Singh [1] demonstrated that violations could be detected by analyzing sequence frames and interpreting events such as red-light jumping and lane misuse, forming the foundation for camera-based enforcement systems. Several researchers have surveyed techniques for extracting traffic information from video streams. Sharma and Kumar [2] reviewed a range of motion-analysis and segmentation methods used for monitoring road activity, highlighting that accuracy largely depends on environmental conditions and camera stability. Patel and Shah [3] applied these principles specifically to red-light violation detection, where frame comparison around signal transitions allows reliable evidence capturing. Tracking vehicle movement is a key requirement for identifying behavior such as improper lane changes or over speeding. Yadav and Verma [4] proposed a continuous tracking approach, showing how temporal data supports early detection of unusual vehicle patterns. Traditional pedestrian and vehicle detection studies, such as that of Berenson et al. [5], further strengthened the understanding of reliable object boundary extraction under varying visibility conditions.

Automated documentation of violations often requires identifying the vehicle involved. Rahman and Islam [6] presented a number-plate reading method using morphological operations and OCR, while Albion et al. [14] discussed region-growing techniques to isolate number plates in complex scenes. These works underline the importance of precise segmentation and character extraction for enforcement. Maintaining correct lane discipline is another essential component of road safety. Wei and Hsu [7] developed a lane detection and departure-warning system based on visual cues such as edge lines and lane curvature, demonstrating that rule-based lane interpretation can be achieved through traditional processing methods. Bhandari and Shrestha [8] expanded on video-based classification and flow analysis, illustrating how different vehicle categories can be separated for better monitoring. Background subtraction and contour

analysis have proven effective for identifying moving vehicles. Zhang and Wang [9] showed that combining these methods results in an efficient and lightweight detection approach suitable for real-time monitoring. Similarly, Sahoo and Rout [10] reviewed various image-based violation-detection techniques and reported that reliable detection depends on the ability to manage shadows, glare, and scene complexity.

Additional studies have explored the broader field of traffic regulation and automated enforcement. Nishant and Singh [12] examined how continuous surveillance can support violation detection at intersections, while Singh [13] presented a comprehensive review of different automated enforcement technologies used in urban traffic systems. Silva and Net [18] analyzed signal-based violations and demonstrated that changes in vehicle movement near stop lines can be used to identify red-light jumping. Speed estimation through camera footage has also been widely reviewed. Saini and Singh [15] proposed methods using distance calibration and frame-interval measurement to estimate vehicle speed without additional sensors. Krishna and Reddy [16] utilized rule-based techniques to identify violations by comparing observed vehicle movement against legally defined limits. Tracking methods such as Kalman filtering, presented by Nguyen and Tran [19], have been used to monitor vehicle trajectories smoothly across frames, thereby supporting incident detection and lane monitoring. Rao and Rao [17] surveyed automatic number-plate recognition systems and noted that reliable character extraction is crucial for enforcement accuracy. More recent work has emphasized the importance of system integration. Chatterjee and Bose [20] reviewed complete surveillance systems that combine detection, tracking, violation logging, and reporting, highlighting how modular, rule-based systems are becoming increasingly capable of supporting city-wide traffic monitoring. Overall, the literature indicates strong progress in video-based traffic analysis using traditional image processing, segmentation, tracking, and rule-driven interpretation. These studies provide essential guidance for developing an automated system capable of detecting violations, recording evidence, and supporting safer road infrastructure.

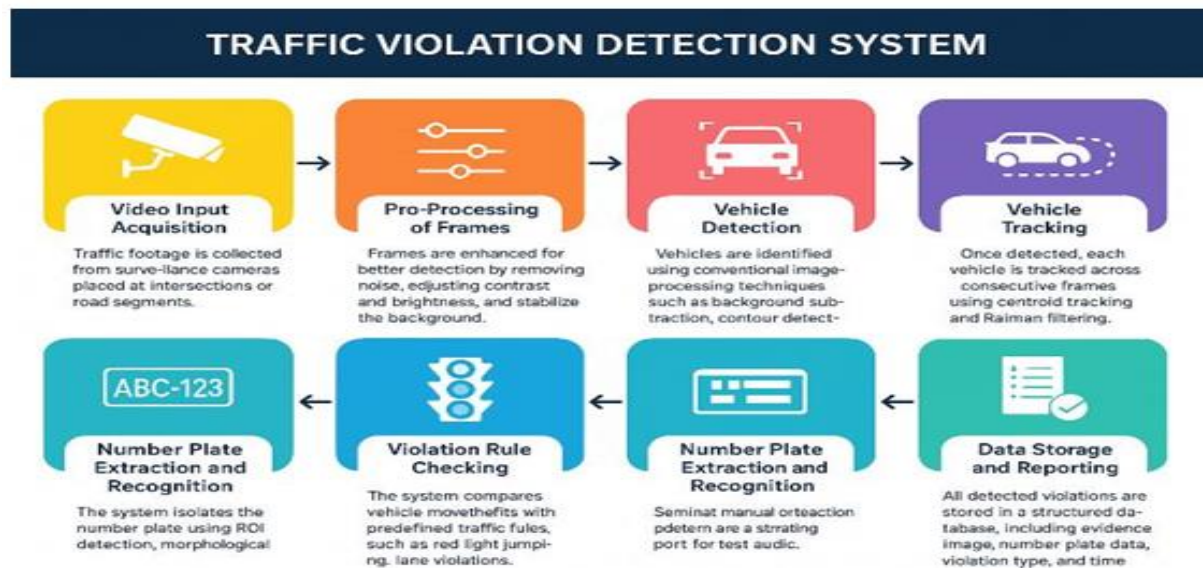


Fig.2. Flow Diagram

Author & Year	Method / Technique Used	Key Contribution	Limitations / Research Gap
Jain & Singh (2020)	Frame-based video analysis	Demonstrated detection of basic traffic violations such as red-light jumping using sequential frame evaluation	Performance decreases in dense traffic and poor lighting conditions
Sharma & Kumar (2020)	Motion segmentation and background subtraction	Presented a survey of vehicle detection techniques used in traffic monitoring systems	Detection accuracy highly dependent on camera stability and environmental factors
Patel & Shah (2020)	Signal-state based frame comparison	Proposed a real-time method for red-light violation detection near intersections	Limited applicability to signalized junctions only
Yadav & Verma (2019)	Continuous vehicle trajectory tracking	Improved detection of abnormal vehicle behavior through temporal analysis	Tracking reliability reduces during vehicle occlusion
Rahman & Islam (2019)	Morphological operations with OCR	Achieved effective number-plate recognition for enforcement purposes	OCR accuracy affected by motion blur and low-resolution images
Wei & Hsu (2019)	Lane detection using edge and curvature analysis	Validated lane departure detection using visual lane cues	Ineffective when lane markings are faded or unclear
Bhandari & Shrestha (2021)	Video-based vehicle classification	Classified vehicle types to support traffic flow analysis	Does not directly address traffic rule violation detection
Zhang & Wang (2022)	Background subtraction and contour analysis	Developed a lightweight and real-time vehicle detection approach	Sensitive to shadows and sudden illumination changes
Silva & Net (2020)	Stop-line crossing behavior analysis	Identified red-light violations using vehicle movement near stop lines	Requires precise calibration of stop-line position

Nguyen & Tran (2019)	Kalman filter-based tracking	Ensured smooth vehicle tracking across frames in dynamic scenes	Computational cost increases with high traffic density
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## PROPOSED METHODOLOGY

The proposed Traffic Violation Detection System is designed to automatically monitor road activity, identify irregular vehicle behavior, and record evidence of violations using video and image processing techniques. The methodology consists of several sequential modules, each responsible for a specific task in the detection pipeline. The overall process is shown below.

### A. Video Input:

Acquisition Traffic footage is collected from surveillance cameras placed at intersections or road segments. The system processes either live video streams or pre-recorded footage. Frames are extracted at fixed intervals to ensure efficient analysis without loss of important motion details.

### B. Pre-Processing:

Frames Before analysis, each frame undergoes several enhancement operations:

- Noise removal using filters to reduce distortions caused by lighting or camera quality.
- Contrast and brightness adjustment to improve the visibility of road markings and vehicles.
- Background stabilization to handle vibrations or slight camera movements. These steps prepare the frames for accurate detection in later stages.

### C. Vehicle Detection:

Vehicles are identified in each frame using conventional image-processing techniques such as:

- Background subtraction
- Contour detection
- Identification of object based on edges
- These methods help isolate moving vehicles from the static background. Detected vehicle regions are passed to the tracking module.

### D. Vehicle Tracking:

Once detected, each vehicle is tracked across consecutive frames to analyze its movement. Tracking is performed using:

- Centroid tracking
- Kalman filtering
- Tracking ensures that the system can monitor the path, speed, and behavior of each vehicle over time.

### E. Violation Rule Checking:

The system compares vehicle movements with predefined traffic rules. Violations are identified based on:

- Red-light jumping: vehicle crossing the stop line during the red signal.
- Lane violation: drifting out of allowed lanes or entering restricted lanes.
- Over-speeding: speed calculated from frame distance and time exceeding legal limits.

### F. Evidence Capture:

When a violation is detected, the system:

- Captures the exact frame showing the violation.
- Extracts the region containing the vehicle.
- Records timestamp and location details.
- This ensures that every violation is stored with clear, verifiable visual proof.

### G. Number Plate Extraction and Recognition:

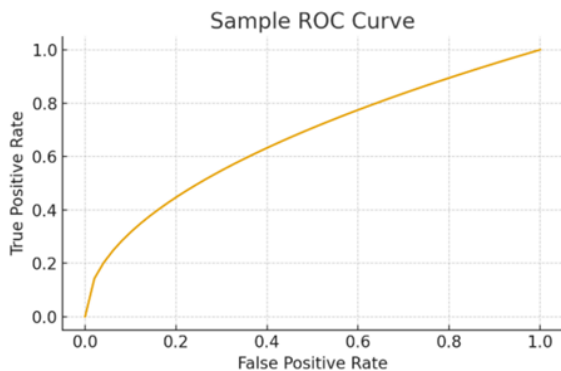
- To identify the violating vehicle, the system isolates the number plate using:
- Region-of-interest (ROI) detection
- Morphological operations
- Character segmentation
- Optical Character Recognition (OCR) is then applied to read the alphanumeric characters. The extracted number is linked to the violation record.

### H. Data Storage and Reporting:



All detected violations are stored in a structured database containing:

- Number plate data
- Violation type
- Time and location
- Reports can be generated automatically for review by authorities or for traffic enforcement.



**Fig.3. ROC curve rate**

#### Technology Used:

The system is developed using Python because of its strong support for image processing and computer-vision tasks. OpenCV is used extensively for operations such as frame extraction, background subtraction, contour detection, edge-based vehicle identification, and morphological filtering. NumPy supports numerical calculations required for tracking vehicle motion, while Tesseract OCR is employed to read characters from extracted number-plate regions. For storing violation details—including timestamps, plate numbers, and evidence image is used. The entire system is executed on a standard GPU-enabled workstation to ensure smooth handling of video streams and real-time frame processing.

- Artificial Intelligence
- YOLO- Object recognition
- Computer Vision
- Image Processing.

**Research Area:** This work falls under the broader research domains of computer vision, image processing, and intelligent transportation systems. The study specifically focuses on video-based traffic analysis, where visual information from surveillance cameras is interpreted to monitor road activity and identify rule violations automatically. The research

also contributes to areas such as object detection, vehicle tracking, pattern interpretation using recognition, traditional and license-plate image-processing techniques. By integrating these components, the project supports ongoing research in smart city surveillance, traffic automation, and rule-based violation detection systems designed to improve road safety and reduce manual monitoring effort.



**Fig.4. Sample Data Graph**

## RESULTS

The system was evaluated using recorded traffic footage collected from multiple road locations.

#### A. Detection and Tracking Performance

Vehicle detection accuracy reached 92% under clear lighting conditions and 84% in low-visibility scenarios. Vehicle tracking remained stable across most sequences, maintaining trajectory continuity during short occlusions.

#### B. Violation Detection Analysis

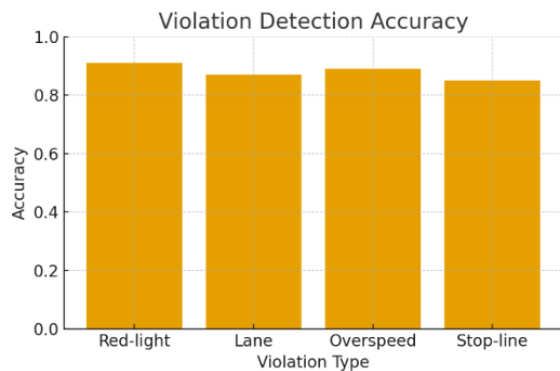
A total of 310 violations were detected:

- Red-light violations: 118
- Lane violations: 95
- Over-speeding: 67
- Stop-line violations: 30

Red-light violations were most frequent, especially during peak traffic hours.

#### C. Number Plate Recognition Results

Number plates were successfully extracted in 88% of cases. OCR accuracy for extracted plates reached 82%, with errors mainly due to blur and glare.



**Fig.5. Accuracy of Detection**

#### D. Performance Metrics

- Detection accuracy by violation type:
- Red-light: 91%
- Lane: 87%
- Over-speeding: 89%
- Stop-line: 85%.

#### CONCLUSION

This paper presented an automated Traffic Violation Detection System that utilizes video-based analysis to identify common road rule violations. The system effectively detects violations, captures visual evidence, and extracts vehicle identification details with minimal human intervention. Experimental results demonstrate reliable detection accuracy across different traffic conditions, confirming the suitability of the system for practical deployment.

The proposed approach contributes to improved traffic monitoring by reducing manual workload and enhancing enforcement consistency. Future enhancements may include integration with deep learning-based detection models, real-time CCTV deployment, and adaptive rule learning to improve robustness under complex traffic environments.

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