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SMART TRAFFIC POLICING: DEEP LEARNING-BASED AUTOMATED E-CHALLAN SYSTEM

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ABSTRACT:

Traffic violations remain one of the leading causes of road accidents, congestion, and enforcement challenges in urban areas. Traditional monitoring systems rely heavily on manual supervision or semi-automated methods, which are often time-consuming, error-prone, and limited in scalability. With the rapid progress of artificial intelligence, particularly in deep learning and computer vision, automated traffic law enforcement has emerged as a promising solution.

This paper presents Smart Traffic Policing, a Deep Learning-Based Automated e-Challan System designed to detect traffic violations in real-time and generate electronic challans without human intervention. The system employs Convolutional Neural Networks (CNNs) for vehicle detection, OCR-based license plate recognition for offender identification, and a rule-based violation detection module that classifies actions such as signal jumping, over-speeding, and helmetless riding. Once a violation is detected, the system automatically cross-verifies vehicle details from a centralized database and issues a digitally authenticated e-challan to the violator through an integrated portal.

Experimental results demonstrate that the proposed framework achieves high accuracy in diverse environmental conditions, including variations in lighting, weather, and traffic density. Compared to conventional surveillance approaches, the system significantly reduces manual workload, improves enforcement transparency, and ensures timely penalty issuance.

By integrating deep learning, computer vision, and IoT-enabled databases, this study highlights the potential of AI-driven governance systems to enhance road safety, enforce compliance, and contribute toward building smarter, safer cities.

1. INTRODUCTION

Urbanization and the rapid increase in vehicle ownership have placed enormous pressure on existing road infrastructure and traffic management systems. As traffic density rises, so do violations such as signal jumping, speeding, helmetless riding, and unauthorized lane changes. These violations not only contribute to road congestion but are also among the primary causes of road accidents and fatalities worldwide. According to recent transport statistics, a significant percentage of traffic accidents could be prevented through stricter and more consistent enforcement of traffic regulations.

Traditional methods of traffic enforcement, which rely heavily on manual policing or semi-automated surveillance systems, are often limited in accuracy and efficiency. Human-dependent approaches suffer from challenges such as limited monitoring capacity, subjectivity in judgment, delays in penalty issuance, and lack of real-time responsiveness. Furthermore, with the increasing volume of vehicles, it becomes nearly impossible for law enforcement personnel to track and penalize all violators effectively.

In this context, the emergence of Artificial Intelligence (AI), Deep Learning, and Computer Vision has introduced new opportunities for automating traffic regulation and penalty enforcement. By leveraging high-definition cameras, Convolutional Neural Networks (CNNs), and Optical Character Recognition (OCR), traffic violations can be automatically detected, vehicle license plates recognized, and offenders identified in real-time. Such systems enable the automatic generation of electronic challans (e-challans), which are seamlessly integrated with government transport databases for swift and transparent penalty issuance.

The proposed system, Smart Traffic Policing, aims to address these gaps by creating an end-to-end automated framework for traffic violation detection and e-challan generation. The key objectives of this work are:

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To design a deep learning-based detection system capable of identifying common traffic violations with high accuracy.
To integrate license plate recognition for automatic offender identification.
To develop a rule-based violation classification mechanism for real-time processing.
To ensure seamless e-challan generation and delivery by linking the system with government vehicle databases.
By combining deep learning algorithms, computer vision techniques, and smart governance infrastructure, this system holds the potential to reduce manual workload, improve enforcement efficiency, enhance public compliance, and ultimately contribute to safer and smarter urban mobility.

2. LITERATURE REVIEW

1. Regulatory & operational context (e-Challan systems)
Automated e-challan systems are already operational in many Indian cities and integrated with national portals for challan lookup and payment — making automatic violation-to-penalty pipelines plausible from an implementation and policy standpoint. Practical deployments also mean systems must satisfy legal/forensic requirements (evidence, timestamping, audit trails).
2. Core tasks & common pipeline

A practical automated e-challan system decomposes into these technical sub-tasks: (1) vehicle detection in video frames, (2) multi-object tracking and speed/trajectory estimation, (3) violation classification (e.g., red-light jump, overspeeding, helmet/no-helmet), (4) ANPR/ALPR (automatic license plate recognition) for identity, and (5) e-challan generation + database cross-check and delivery. Each subtask has an active research literature and established engineering patterns.
3. Vehicle detection & real-time models
State-of-the-art single-stage detectors (YOLO family, recent YOLOv8/YOLOv9 variants, and lightweight backbones) are commonly used for real-time vehicle detection in surveillance streams because they balance accuracy and latency; many recent traffic-violation papers use YOLO variants as the detection backbone. For edge deployments, model compression and TensorRT/quantization are important to meet throughput constraints.
4. Multi-object tracking (MOT) & speed estimation
Accurate tracking is essential for associating vehicles across frames to determine speed, lane behavior, or signal-violations. DeepSORT/ByteTrack and more recent detection-based MOT methods are widely used; surveys highlight tradeoffs between accuracy, identity switches, and real-time performance in crowded scenes. Monocular speed estimation methods (homography + tracking or calibrated monocular approaches) can produce sufficiently accurate speed estimates for enforcement when camera calibration and perspective corrections are applied.
5. Violation classification (rules & vision)
Vision-based rule detection (e.g., crossing the stop line during red, crossing lane boundaries, not wearing helmets) is typically implemented by combining object detection + tracking + geometric/rule checks (line crossing, ROI triggers). Recent works show robust red-light and helmet detection pipelines using deep detectors (YOLO variants) with post-processing rules to reduce false positives.
6. ANPR / License plate recognition (ALPR)
ALPR remains a mature but challenging component (motion blur, low resolution, occlusion, plate styles). Modern end-to-end ALPR architectures (detection → plate cropping → recognition) use deep networks and can be augmented with super-resolution or specialized OCR for low-res plates; edge-optimized ALPR models and quantized pipelines have been demonstrated for real-time constraints. Ensuring accuracy across diverse plate formats (regional variations) and nighttime conditions is a recurring engineering concern.

3. METHODOLOGY

The operational use of this identical technology in the invention of "automatic traffic f o checks century utilising profound learning" is highlighted in the methodology chapter. One such study discusses deep CNN, edge detection, data collection, and equipment setup, but it also discusses object identification in relation to retrieval. The instantaneous e-challan century (aecg) framework is divided into three main stages. Videos and pictures initially appear to have been captured using a camera.

3.1 Convolutional Neural Network

Convolutional neural networks (CNNs) are utilised in many applications, including photo identification and classifiers. In addition to its broad usage in analysis and classification, convolutional neural networks were also frequently used for the practice area after all skincare routine identity [12].

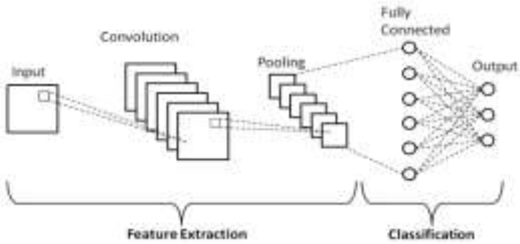

Fig.CNN Architecture

3.1.1 Convolution Layer

Urine creation is activated by the convolution layer, which also attempts to identify peripheral, mitered, and specular maps within these underpinnings, such as succeeding layers that fully recognise basic visual aspects.

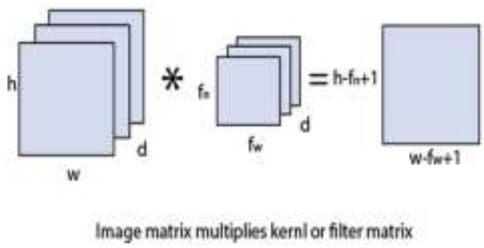

Fig. Convolution Layer structure

3.2 Canny Edge Detection algorithm

A key element of a vision-based combat strategy would be canny thresholding. Canny Edge has been used to the presidential candidate areas that are acknowledged even by deep CNN in order to circumvent the limitations, yes, CBS News, but instead create an effective demarcation delimitation. Even if the same contingents are present, the above stage separates the perimeters after all automobiles. The Osi heuristic consists of four walk practices, where each step carries out particular actions as well as procedures.

1. Gaussian blur: the technique begins by trying to apply greyscale to the image. The aforementioned reduces specificity and smoothes over noises, preparing its image for thresholding.
2. Calculating the gradient: shrewd uses its gradient to identify regions with significant frequency improvements. One of these aids in locating corners.
3. Non-maximum blocking: this specific technique preserves huge corners while erasing fragile ones. One skinnier line is produced by the maintenance of merely the municipal limits along the perimeters.
4. Double: shrewd connects several threshold levels: a minimum bar complete or a low standard complete place that might build the final big and strong back edge. The aforementioned aid in filtering out loud noises.
5. Edge monitoring using cyclic: in addition to attempting to examine this same interconnect after all neighbouring pixels, cleverly link the perimeters against form finish curves.

3.3 Hardware setup

The base Indeed, our plan seems to be built on robust functionality, as evidenced by the cranberry pi4 desktop, personal desktop, one rising main camera, and necessary perivascular components. One of the benefits of having a primary camera is that it may be used to take real-world vehicle photos and use a GSM modem to help with SMS notifications. Below is a configuration of the physical components.

Fig. Hardware Setup

4 EXPERIMENTAL RESULTS

The usage of such a large data set is the key cornerstone of a project's success. We've now taken a lot of diverse photos, including ones of drivers, bicycles, and motorhomes that are used to train human design and to show that the plan may be credible despite its apparent cost. Researchers used a simulation model of one real set of conditions in our exploratory study, in addition to entering photographs into a fully automated e-challan new generation (aecg) framework. The first image depicted a challenging circumstance, necessitating the intentional application of chromatic aberration. This second image represented a clear but angular situation.

Fig. Image input 1

Fig. Image input 2

Output

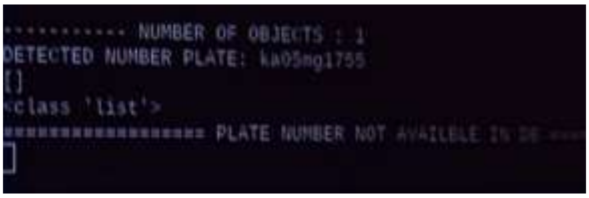

Fig. Image output Results

Fig. Challan Generated

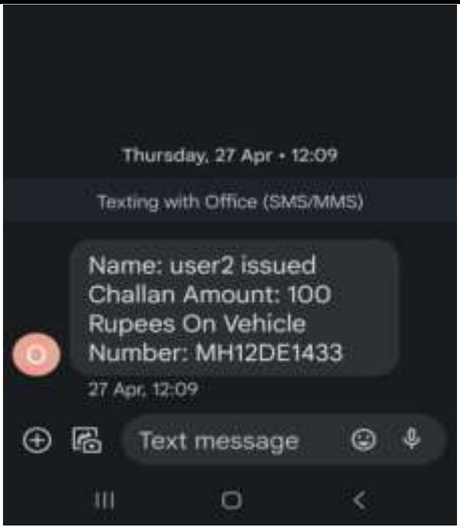

Fig. Generated SMS for E challan

After closely examining the results, the same aecg system successfully identified the same violations in the images and triggered the same generation consoles of such an e-challan.

5 CONCLUSION

The study presented an AI-driven framework for automated traffic violation detection and e-challan generation, demonstrating the potential of deep learning and computer vision in transforming conventional traffic law enforcement. By integrating Convolutional Neural Networks (CNNs) for vehicle and violation detection, OCR-based license plate recognition, and a rule-based classification system, the proposed solution effectively automates the entire process of identifying offenders and issuing penalties in real time.

The experimental results indicate that such a system can operate reliably under diverse traffic conditions, reducing the dependency on manual supervision while enhancing transparency, accuracy, and timeliness in penalty enforcement. Moreover, the integration with centralized transport databases ensures seamless offender identification and facilitates the digital dispatch of challans, thereby streamlining governance processes.

Beyond automation, the framework contributes to broader societal goals by encouraging behavioral compliance, reducing traffic accidents, and supporting the vision of smart cities. While current limitations such as occlusion, poor lighting, and database integration challenges remain, future enhancements could include the use of edge AI devices, 5G-enabled IoT sensors, and advanced ensemble deep learning models to improve efficiency, scalability, and robustness.

In conclusion, the Smart Traffic Policing system represents a significant step toward intelligent, technology-enabled law enforcement that can ease the burden on human officers, promote safer road practices, and foster sustainable urban mobility in the years to come.

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