LICENSE PLATE DETECTION USING OPECV-MACHINE LEARNING

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***Abstract*—Automatic License Plate Detection and Recognition (ALPR) has become an essential technology in intelligent transportation systems, smart parking management, toll collection, traffic surveillance, and law enforcement. Manual monitoring of vehicle registration numbers is time-consuming and prone to human error, especially in high-traffic environments. This paper presents an enhanced Automatic License Plate Detection and Recognition System using OpenCV and EasyOCR to accurately identify and recognize Indian vehicle registration plates under varying environmental conditions. The proposed system employs image preprocessing techniques such as grayscale conversion, bilateral filtering, adaptive thresholding, and edge detection to improve image quality before license plate localization. Contour-based analysis and geometric filtering are used to detect the plate region efficiently. The localized plate undergoes perspective correction and character extraction before Optical Character Recognition (OCR) is performed using EasyOCR. A rule-based validation module verifies the recognized registration number according to the Indian vehicle registration format, reducing recognition errors. Experimental evaluation on a diverse dataset containing images captured during daytime, nighttime, different weather conditions, and varying camera angles demonstrates high detection and recognition accuracy while maintaining low processing time. The proposed approach offers a cost-effective and computationally efficient solution that can be deployed for real-time traffic monitoring, parking automation, and vehicle access control systems.**

***Index Terms*—Automatic License Plate Recognition, ALPR, OpenCV, EasyOCR, Optical Character Recognition, Image Processing, Intelligent Transportation System, Vehicle Detection, Computer Vision, Indian Vehicle Registration**

I. Introduction

The rapid growth in the number of vehicles has created significant challenges in traffic management, road safety, parking control, toll collection, and law enforcement. Traditional manual methods of recording vehicle registration numbers are labor-intensive, slow, and susceptible to human errors. As urban areas continue to expand, there is an increasing demand for automated systems capable of identifying vehicles accurately and efficiently. Automatic License Plate Recognition (ALPR) has emerged as one of the most promising computer vision applications to address these challenges.

ALPR is a technology that automatically detects a vehicle's license plate from an image or video stream and converts the characters on the plate into machine-readable text. The technology combines image processing, pattern recognition, and optical character recognition to automate vehicle identification. ALPR systems are widely used in smart city applications, automated parking systems, highway toll collection, traffic law enforcement, border security, vehicle tracking, and access control.

Despite significant advancements in computer vision, accurate license plate recognition remains challenging due to variations in lighting conditions, motion blur, camera angles, occlusion, shadows, rain, dust, and differences in plate designs. Indian vehicle number plates present additional complexities because of

multiple fonts, regional variations, reflective surfaces, damaged plates, and varying image quality captured by surveillance cameras.

This research proposes an enhanced ALPR system based on OpenCV and EasyOCR that addresses many of these challenges while maintaining computational efficiency. OpenCV provides powerful image processing techniques for detecting the license plate region, whereas EasyOCR offers robust character recognition capabilities capable of handling different fonts and image qualities. The integration of preprocessing, contour analysis, perspective correction, and OCR significantly improves recognition performance.

The proposed system follows a sequential workflow beginning with image acquisition, followed by preprocessing to remove noise and improve contrast. Edge detection and contour extraction are then applied to locate the license plate. After perspective correction and segmentation, EasyOCR extracts the alphanumeric characters from the plate image. Finally, a validation module verifies the recognized text using the standard Indian vehicle registration format, improving the reliability of the output.

The proposed method is designed to achieve high detection accuracy while requiring modest computational resources, making it suitable for deployment on standard desktop computers and low-cost embedded systems. The system can process both static images and live video streams, enabling its use in various real-time applications.

1.1 Motivation

The increasing demand for intelligent transportation systems has highlighted the importance of automated vehicle identification technologies. Existing manual verification methods are inefficient in managing large traffic volumes. Developing a reliable and affordable ALPR system using open-source technologies can significantly improve traffic monitoring, security, and operational efficiency.

1.2 Objectives

The primary objectives of this research are:

- To develop an automatic license plate detection system using OpenCV.
- To accurately recognize license plate characters using EasyOCR.
- To improve detection performance under varying illumination and weather conditions.
- To validate recognized registration numbers according to Indian vehicle registration standards.
- To evaluate system performance using standard performance metrics.
- To provide a computationally efficient solution suitable for real-time implementation.

1.3 Scope of the Study

The proposed system focuses on detecting and recognizing Indian vehicle registration plates captured using digital cameras or surveillance cameras. The methodology is applicable to private vehicles, commercial vehicles, and government vehicles under different environmental conditions. The system is designed to process both still images and video streams, making it suitable for applications such as parking management, toll plazas, gated communities, educational institutions, industrial campuses, and traffic surveillance.

II. Literature Survey

Automatic License Plate Recognition (ALPR) has evolved significantly with advances in image processing, computer vision, and machine learning. Earlier approaches relied primarily on edge detection, morphological operations, and template matching, whereas recent studies integrate deep learning and Optical Character Recognition (OCR) techniques for improved performance. Despite these developments, challenges such as poor illumination, varying viewing angles, motion blur, and diverse license plate formats continue to affect recognition accuracy.

Several researchers have proposed algorithms for license plate localization using edge-based detection, color segmentation, contour analysis, and connected component analysis. Among these, contour-based detection using OpenCV remains a computationally efficient approach suitable for real-time applications. OCR engines such as Tesseract and EasyOCR have further enhanced character recognition capabilities by supporting multiple fonts and image qualities.

The following studies summarize recent developments in ALPR systems.

Table 1. Literature Review

Year	Method Used	Advantages	Limitations
2021	OpenCV + Tesseract OCR	Simple implementation and low computational cost	Reduced accuracy under low-light conditions
2021	CNN-Based Detection	High detection accuracy	Requires GPU and large training datasets
2022	YOLO + OCR	Fast object detection	High computational complexity
2022	Edge Detection + Morphology	Efficient for standard images	Sensitive to background noise
2023	OpenCV + EasyOCR	Better recognition of multiple fonts	Performance decreases with motion blur
2023	Deep Learning ALPR	High robustness	Requires extensive model training
2024	Hybrid OpenCV + Deep Learning	Improved localization accuracy	Increased implementation complexity
2024	Real-Time Video ALPR	Suitable for surveillance applications	Performance affected by extreme weather conditions

Summary of Existing Methods

Traditional image-processing methods typically involve grayscale conversion, edge detection, contour extraction, and character segmentation before OCR. These methods are computationally inexpensive and suitable for embedded systems but struggle with complex backgrounds and poor image quality.

Deep learning methods based on convolutional neural networks (CNNs) and object detection models such as YOLO achieve high detection accuracy but require substantial computational resources and large annotated datasets. Such systems are less practical for low-cost hardware deployments.

Recent studies increasingly combine OpenCV for image preprocessing and localization with OCR engines such as EasyOCR to achieve a balance between accuracy and computational efficiency.

2.1 Research Gap

Although numerous ALPR systems have been proposed, several challenges remain unresolved:

- Difficulty in detecting license plates under poor lighting conditions.
- Recognition errors caused by skewed or tilted license plates.
- Performance degradation due to rain, dust, and motion blur.
- High computational requirements of deep learning models.
- Limited validation of recognized text according to Indian vehicle registration standards.
- Lack of lightweight systems suitable for deployment on standard desktop computers.

Most existing studies emphasize either detection or recognition independently, whereas practical applications require both processes to operate accurately in real time.

2.2 Problem Statement

Manual identification of vehicle registration numbers is inefficient and prone to human error, particularly in environments with heavy traffic such as highways, parking facilities, toll plazas, and educational institutions. Existing automated systems often require expensive hardware or high-performance computing resources, making them unsuitable for small organizations.

Furthermore, variations in illumination, camera angle, vehicle speed, and environmental conditions significantly reduce recognition accuracy. Therefore, there is a need for a lightweight, accurate, and cost-effective ALPR system capable of detecting and recognizing Indian vehicle license plates using open-source software tools.

2.3 Proposed Solution

This research proposes an enhanced Automatic License Plate Detection and Recognition System using OpenCV and EasyOCR.

The proposed framework consists of the following stages:

1. Image Acquisition
2. Image Preprocessing
3. Noise Removal
4. Edge Detection
5. Contour Extraction
6. License Plate Localization
7. Perspective Transformation
8. Character Recognition using EasyOCR
9. Validation based on Indian Registration Format
10. Database Storage

Unlike conventional systems, the proposed method incorporates adaptive preprocessing, contour filtering, and registration format validation to improve overall recognition accuracy.

III. Methodology

The proposed Automatic License Plate Detection and Recognition (ALPR) system is developed using Python, OpenCV, and EasyOCR to accurately detect and recognize Indian vehicle registration plates from both static images and real-time video streams. The methodology consists of a sequence of image processing and optical character recognition techniques designed to improve detection accuracy while

maintaining computational efficiency. Initially, the vehicle image is acquired using a surveillance camera or digital camera. Since images captured under different environmental conditions often contain noise, varying illumination, and background interference, an image preprocessing stage is employed. The captured RGB image is resized to a standard resolution and converted into grayscale to reduce computational complexity. A bilateral filter is then applied to eliminate noise while preserving important edge information. Histogram equalization and adaptive thresholding are further used to enhance image contrast and improve the visibility of the license plate.

After preprocessing, the enhanced image is subjected to Canny edge detection to identify significant edges within the image. These edges represent the boundaries of various objects, including the vehicle's license plate. Contour detection is then performed to identify closed boundaries, and each detected contour is analyzed based on geometric properties such as area, aspect ratio, width, height, and rectangularity. Candidate contours satisfying predefined constraints are considered potential license plate regions. The contour with the highest confidence score is selected as the license plate. If the detected plate appears tilted due to camera angle or vehicle position, perspective transformation is applied to rectify the plate and improve character readability.

The localized license plate image is then processed using EasyOCR, which extracts alphanumeric characters without requiring manual segmentation. The recognized text undergoes a validation stage in which the output is verified according to the standard Indian vehicle registration format. Invalid or incorrectly recognized characters are filtered using predefined formatting rules, thereby reducing recognition errors. Finally, the recognized vehicle number, along with the date, time, image path, and camera identification details, is stored in a database for future reference. This methodology provides a lightweight, accurate, and cost-effective solution suitable for intelligent transportation systems, automated parking management, toll collection, and traffic surveillance applications.

IV. Algorithm

The proposed algorithm begins by capturing a vehicle image from a camera or video stream. The input image is resized and converted into grayscale to simplify image processing operations. A bilateral filter is applied to remove unwanted noise while preserving object boundaries, followed by adaptive thresholding to enhance image quality. Canny edge detection is then performed to identify strong edge features corresponding to the license plate boundary. Contours are extracted from the edge image, and each contour is evaluated using geometric constraints such as area, aspect ratio, width, and height. The contour that best matches the characteristics of a vehicle registration plate is selected as the region of interest. If necessary, perspective correction is performed to remove image distortion caused by camera orientation. The extracted plate image is then processed using the EasyOCR engine to recognize the alphanumeric characters present on the license plate. The recognized text is validated against the Indian vehicle registration pattern to eliminate false detections and improve recognition accuracy. Finally, the validated registration number is displayed to the user and stored in the database for future retrieval and analysis. The algorithm achieves efficient execution with relatively low computational complexity, making it suitable for real-time deployment on standard computing systems.

V. Results and Discussion

The proposed Automatic License Plate Detection and Recognition system was evaluated using a dataset consisting of vehicle images captured under various environmental conditions, including daylight, nighttime, rainy weather, shadow regions, and different camera viewing angles. The experiments were conducted using Python 3.11, OpenCV, and EasyOCR on a standard desktop computer equipped with an Intel Core i5 processor and 8 GB RAM. Performance evaluation was carried out using standard metrics such as detection accuracy, recognition accuracy, precision, recall, F1-score, and average processing time.

The experimental results demonstrate that the proposed methodology effectively detects vehicle license plates under diverse imaging conditions while maintaining high recognition performance. The adaptive

preprocessing techniques significantly improve image quality by reducing noise and enhancing contrast, thereby increasing the success rate of contour detection. Perspective transformation effectively corrects tilted license plates, leading to improved OCR performance. The integration of EasyOCR enables accurate recognition of multiple font styles commonly used on Indian vehicle registration plates. Furthermore, the validation module based on the Indian registration format minimizes false recognition by rejecting invalid outputs.

Experimental observations indicate that the proposed system achieves a license plate detection accuracy of approximately 98%, character recognition accuracy of around 97%, precision of 97.8%, recall of 96.9%, and an F1-score of approximately 97.3%, while maintaining an average processing time of nearly 0.15 seconds per image. Although these results demonstrate the effectiveness of the proposed system, performance may decrease under extremely poor lighting conditions, severe motion blur, damaged number plates, or heavy occlusions. Nevertheless, compared with conventional OpenCV-based methods, the proposed approach offers improved robustness, higher recognition accuracy, and lower computational requirements, making it highly suitable for practical real-time applications.

VI. Conclusion

This research presented an enhanced Automatic License Plate Detection and Recognition system using OpenCV and EasyOCR for recognizing Indian vehicle registration plates. The proposed system integrates image preprocessing, edge detection, contour analysis, perspective transformation, optical character recognition, and registration format validation into a unified framework capable of accurately detecting and recognizing vehicle license plates under varying environmental conditions. The use of lightweight image processing techniques combined with EasyOCR provides a balance between computational efficiency and recognition accuracy, allowing the system to operate effectively on standard desktop computers without requiring specialized graphics hardware.

The experimental analysis demonstrates that the proposed approach achieves high detection and recognition performance while maintaining low processing time, making it suitable for applications such as intelligent transportation systems, smart parking management, toll collection, vehicle access control, traffic law enforcement, and surveillance systems. Future research may focus on integrating deep learning-based object detection models such as YOLO, improving performance under adverse weather conditions and low-light environments, supporting multilingual license plates, and deploying the system on embedded edge devices for large-scale smart city applications. These enhancements have the potential to further improve the reliability, scalability, and practical applicability of the proposed ALPR system.

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