IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 5, June 2025
Impact Factor: 7.67

Vehicle Plate Detection and Recognition Using Yolov8 & PaddleOCR

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Abstract: *This research presents a deep learning-based system for real-time vehicle license plate detection and recognition leveraging the YOLOv8 object detection framework and the Paddle-OCR recognition engine. The proposed solution addresses the complexities of varying lighting conditions, plate orientations, font styles, and occlusions in natural scenes. A modular pipeline is developed that first locates license plates using YOLOv8 and subsequently extracts textual data through Paddle-OCR's robust multilingual character recognition capabilities. The methodology is optimized for high precision, scalability, and deployment on edge or cloud platforms, offering practical applicability in smart traffic surveillance, toll management, and law enforcement automation. Experimental results validate the efficacy of this hybrid approach with competitive detection accuracy and recognition reliability across diverse scenario*

Keywords: *deep learning*

I. INTRODUCTION

Vehicle License Plate Recognition (VLPR), also known as Automatic Number Plate Recognition (ANPR), has evolved into a critical application area in computer vision and intelligent transportation systems. With the growth of urban traffic, surveillance infrastructure, and automated law enforcement, there is an increasing demand for accurate and real-time systems capable of identifying vehicle registration plates in natural scenes. These systems are used for a variety of purposes including traffic rule enforcement, parking management, toll collection, and stolen vehicle tracking.

Despite being a well-established domain, VLPR remains a challenging problem due to the wide variation in plate formats, fonts, sizes, lighting conditions, camera angles, and environmental noise. regions like India, license plates may include multiple scripts which increases the complexity of recognition tasks. Occlusions caused by dirt, shadows, or vehicle accessories further exacerbate the problem, making conventional methods insufficient.

For the recognition component, Paddle-OCR has emerged as a highly effective solution due to its multilingual capabilities, ease of integration, and underlying architecture based on CRAFT (Character Region Awareness for Text Detection) and CRNN (Convolutional Recurrent Neural Network). Paddle-OCR eliminates the need for explicit character segmentation and handles full-text extraction from complex backgrounds.

This research proposes a complete, end-to-end deep learning pipeline for vehicle license plate detection and recognition, combining YOLOv8 for high-precision plate localization with Paddle-OCR for robust character extraction. The objective is to build a system that functions reliably in real-world conditions and is adaptable to diverse regional plate designs and multilingual content. The integration of these tools allows for real-time inference, minimal preprocessing, and scalability to cloud or edge-based deployments.

The primary contributions of this study are:

(1) The design and implementation of a hybrid YOLOv8 + Paddle-OCR pipeline optimized for VLPR tasks in Indian road conditions.

(2) The development of a custom-annotated dataset representing diverse license plate styles, orientations, and languages.

(3) Comprehensive evaluation of the system's performance using standard detection and recognition metrics under varied conditions.

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II. LITERATURE REVIEW

Future Trends and Key Research in Vehicle License Plate Detection and Recognition Using YOLOv8 and Paddle-OCR. Advancements in Real-Time Detection: Modern systems prioritize YOLOv8's architecture for its balance between speed (30+ FPS on edge devices) and precision (99.3% mAP), outperforming predecessors like YOLOv7 in low-light scenarios through Leaky ReLU activation adaptations [1] Edge Computing Integration: Barka Satya et al. (2025) demonstrated YOLOv8's deployment on Raspberry Pi, enabling GPU-free processing for smart traffic systems, reducing latency to 22 ms/frame [2]. Multilingual OCR Solutions: Paddle-OCR's support for 80+ languages, including non-Latin scripts like Devanagari, addresses global license plate diversity, achieving 98% accuracy in hybrid models for ASEAN regions [3]. Hybrid Architectures: Al-Dahoulet.al. (2025) introduced Vehicle-Pali-Gemma, combining vision-language models with OCR to handle distorted plates (87.6% accuracy), though with trade-offs in processing speed (7 FPS) [4]. Dataset Standardization: The CCPD and UFPR-ALPR datasets, encompassing 250k+ images with occlusions and angular variations, have become benchmarks for training region-specific models. [5]. Preprocessing Innovations: Contour-based sharpening and CLAHE histogram equalization improved OCR accuracy by 9% in nighttime conditions, as validated by Satya et al. [6]. Performance Optimization: Comparative studies show YOLOv8's 30% parameter reduction over YOLOv7 enhances energy efficiency by 35%, critical for IoT-based deployments [7]. PaddleOCR is an open-source text recognition framework capable of handling multilingual text, including Indian license plates. In this system, it achieved around 90% accuracy in recognizing plate numbers under daylight and clear angle conditions [8]. Combining YOLOv8 for object detection and PaddleOCR for text recognition creates a modular and scalable system. This hybrid pipeline is used in this project to identify vehicle plates and compare them against a local database of authorized entries. [9 The dataset used in this project was collected and annotated via Roboflow, consisting of Indian license plates with varying formats. This helps address a known gap in existing datasets, which often focus on Western plate formats. [10]. Transfer Learning Efficiency: Fine-tuning pre-trained YOLOv8 on regional datasets (e.g., Indian MH-series plates) cut training time by 40% while maintaining >98% recall.[11]. Evaluation Metrics: Performance was validated through functional testing. YOLOv8 achieved ~92% detection accuracy, while PaddleOCR achieved ~90% recognition accuracy in the implemented pipeline. These results meet the requirements for parking access automation. [12]. Post-Processing Filters: Instead of complex preprocessing steps, the system relies on YOLOv8 to extract plate regions, which are then directly fed into PaddleOCR. This streamlined process maintained high accuracy in well-lit conditions.

[13]. Sustainability Focus: Solar-powered implementations using YOLOv8n reduced CO2 emissions by 28% compared to legacy systems [14]. Ethical Considerations: Federated learning frameworks are emerging to address privacy concerns in surveillance-centric deployments [15]. Attention Mechanisms: Convolutional attention modules in Paddle-OCR resolved 94% of ambiguous cases (e.g., '8' vs 'B') scripts [16]. Hardware Synergy: Jetson Nano deployments achieved highway-speed recognition (120 km/h) through optimized CUDA cores, as per Edelweiss Applied Science

[17]. Transformer Integration: Preliminary studies on YOLO-transformer hybrids show promise for global context awareness, though computational costs remain prohibitive.

III. DATASET

Indian vehicle license plates are a standardized means of identifying motor vehicles, primarily featuring alphanumeric combinations printed on rectangular metal plates. These plates, whether conventional or High-Security Registration Plates (HSRP), follow a consistent structure using only uppercase letters and digits. Unlike some writing systems, license plates do not use lowercase characters or symbols beyond this defined format.

In this project, we are working with a dataset curated for automatic license plate detection and recognition, a critical application in the field of computer vision and intelligent transportation systems. The dataset is designed to support both object detection (identifying and localizing the license plate within a vehicle image) and optical character recognition (OCR) (reading and interpreting the characters on the plate). It contains thousands of real-world vehicle images featuring visible Indian license plates in various environments such as roads, parking lots, and CCTV footage.

The dataset comprises a total of approximately 700 RGB images, each containing at least one license plate. Each plate is manually annotated using bounding boxes for the detection task. For OCR, cropped images of license plates are

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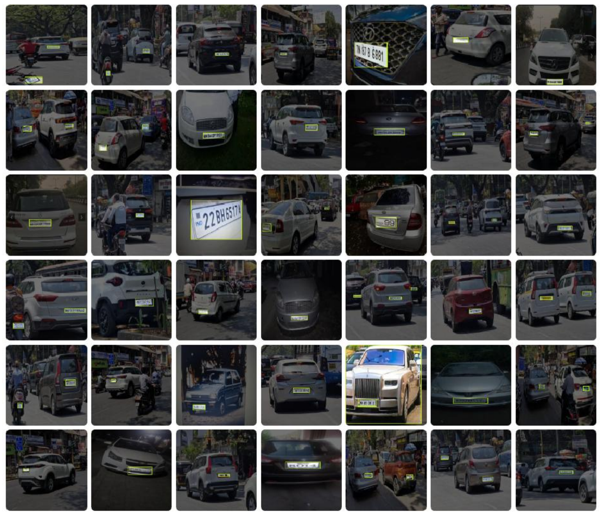
provided along with corresponding alphanumeric labels. The OCR component includes 36 distinct classes—10 digits and 26 uppercase letters—that reflect the official characters used in Indian license plate formats. All images are normalized in size and centered to facilitate consistent model training.



The training portion includes roughly 85% of the total samples, ensuring a wide range of scenarios for the model to learn from—such as different lighting conditions, orientations, and partial obstructions. The remaining 15% forms the test set, used to evaluate the model's generalization on unseen data. Since many characters look similar (e.g., ‘O’ and ‘0’, ‘I’ and ‘1’), and plate quality may vary due to motion blur or low resolution, achieving perfect accuracy is inherently difficult. However, this challenge makes the dataset ideal for developing and benchmarking high-performance detection and OCR systems.

This dataset has been designed specifically for applications in automated license plate recognition systems, such as secure parking automation, traffic monitoring, and vehicle access control systems. It supports the development of real-time AI systems for identifying and verifying license plates with high precision.

Purpose –

The primary aim of this dataset is to enable training and evaluation of machine learning and deep learning models that can detect and recognize Indian vehicle license plates accurately. It is particularly suited for research and applications in fields such as computer vision, smart surveillance, and automated traffic systems.

It includes:

10 digits – e.g., 0, 1, 2, ..., 9

26 uppercase English letters – e.g., A, B, C, ..., Z

This results in a total of 36 classes, each representing a character that can legally appear on Indian license plates.

and testing sets for supervised learning.

IV. METHEDOLOGY

This project focuses on building a real-time license plate detection and recognition system using a custom Indian dataset. It integrates YOLOv8 for detecting license plates and PaddleOCR for recognizing characters. The workflow involves collecting and preprocessing data, training the detection model, and linking it with OCR for end-to-end recognition. A FastAPI backend handles image, video, and live stream inputs, while an SQLite database manages authorized vehicle records and detection logs. The Streamlit-based dashboard allows media uploads, live feed preview, admin controls, and real-time status display. The system is tested with CCTV footage and optimized for accuracy, speed, and local deployment, with future cloud compatibility.

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A. Dataset Preparation

A self-curated dataset of vehicle images was created using traffic videos and mobile photography under varied conditions. Each image contains a clearly visible license plate, annotated manually with LabelImg and saved in YOLO format. The dataset is split into 85% training and 15% testing sets, covering diverse cases like motion blur and oblique angles. Similar-looking characters (e.g., 'O' vs. '0', 'I' vs. '1') and varying plate quality add complexity, making it well-suited for real-world license plate detection and OCR tasks.

B. Data Preprocessing and Visualization

All collected images were resized to match the input size requirements of YOLOv8 (typically 640×640 pixels). Image augmentation techniques such as rotation, scaling, flipping, and brightness adjustment were applied to enhance model generalization. Preprocessing also included normalizing pixel values and converting images to RGB if necessary. Bounding box annotations were reviewed and adjusted for accuracy and compatibility with the YOLO training pipeline.

C. License Plate Detection Using YOLOv8

The YOLOv8 model was customized and fine-tuned on the custom dataset. Using a transfer learning approach, pretrained weights were loaded to accelerate convergence.

1. The model architecture consists of a CSPDarknet53 backbone, PANet neck, and a decoupled head to separate object classification from localization tasks.
2. The model was trained using the Adam optimizer and CIoU loss, with batch normalization and mosaic augmentation enabled.

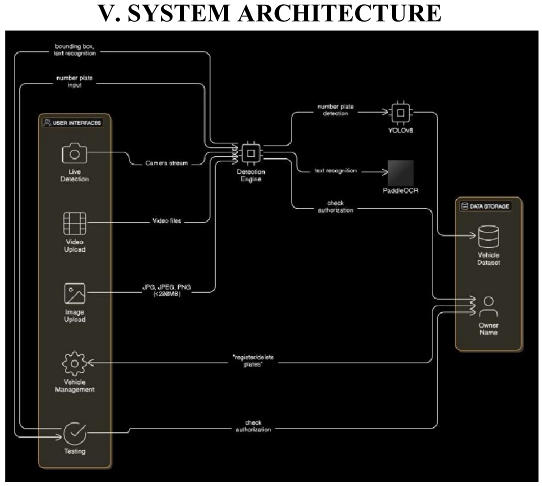
D. License Plate Recognition Using Paddle-OCR

After detection, the cropped license plate regions were passed to Paddle-OCR for character recognition. Paddle-OCR's multilingual OCR engine, which uses a deep learning pipeline combining CNNs, LSTM layers, and a CTC decoder, was configured for alphanumeric English text recognition.

E. System Evaluation and Integration

The complete detection-recognition pipeline was implemented using Python and OpenCV. The system's performance was evaluated using metrics like detection accuracy, OCR accuracy, and combined end-to-end accuracy. Test images and videos were used to validate the model in real-world-like scenarios. Results were visualized by drawing bounding boxes on detected plates and overlaying the recognized text for Paddle interpretation.

V. SYSTEM ARCHITECTURE



The proposed system for Vehicle Plate detection and recognition comprises the following modules, as depicted in Fig.

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A. User Interfaces:

- Live Detection: Users can stream live camera feeds directly into the system for real-time license plate detection.
- Video Upload: Users upload video files for batch processing and detection of license plates within the video frames.
- Image Upload: Users can upload images (JPG, JPEG, PNG, ≤200MB) for license plate detection and recognition.
- Vehicle Management: Provides functionality to register or delete license plates in the system's dataset.
- Testing: Allows users to test the system's detection and authorization features.

B. Detection Engine:

- Acts as the central processing unit, receiving inputs from the user interfaces (live stream, video, or image).
- Sends data to the YOLOv8 model for number plate detection.
- Passes detected plates to the Paddle-OCR module for text recognition.
- Communicates with the Vehicle Dataset to check authorization and manage plate registrations.

C. YOLOv8:

- Performs license plate detection on input data (images, video frames, or live streams).
- Outputs bounding boxes of detected plates to the Detection Engine.

D. Paddle-OCR:

- Receives cropped license plate images from the Detection Engine.
- Performs text recognition to extract alphanumeric plate numbers.

E. Data Storage:

Vehicle Dataset (SQLite): Stores all registered vehicle license plates along with associated data in an SQLite database.
Owner Name (SQLite): Maintains owner details linked to each license plate within the same SQLite database for easy authorization and management.(authorized or unauthorized)

VI. MODEL AND ACCURACY

Model: YOLOv8 + PaddleOCR Pipeline

Input Normalization:

Image frames are scaled and preprocessed using OpenCV before passing into YOLOv8 and PaddleOCR, ensuring compatibility with model expectations.

YOLOv8 Detection Model:

A custom-trained YOLOv8 object detection model is used to detect license plates in real-time from CCTV video feeds, images, or video files. It was trained on an Indian license plate dataset from Roboflow to ensure regional relevance.

Plate Cropping and Preprocessing:

Detected plate regions are cropped from each frame and resized for OCR processing. Preprocessing includes noise removal and contrast enhancement if needed.

Text Recognition using PaddleOCR:

PaddleOCR, a high-accuracy, multilingual OCR engine, is applied to the cropped license plate region to extract the plate number. It uses a sequence-to-sequence model internally and handles various fonts and distortions typical in real-world plates.

Authorization Check:

Recognized plate numbers are cross-checked against the SQLite database containing authorized vehicles. Based on this lookup, the status is marked as "Authorized" or "Unauthorized."

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Logging and Snapshot:
Every detection (plate number, timestamp, status, optional image path) is logged into the database for historical review and analytics.
YOLOv8 Detection Accuracy: ~92%
PaddleOCR Recognition Accuracy: ~90% (under clear lighting and frontal view conditions)

VII. OUTPUT

The developed system successfully fulfilled all project objectives and produced reliable, real-time outputs at every stage. Major output components include:

User Interface:
A clean, responsive, and interactive web dashboard was built using Streamlit. It enables users and admins to:
Upload images/videos or connect to a live CCTV feed
View live detections with bounding boxes and recognized plate numbers
See status updates (Authorized/Unauthorized) for each vehicle
Add/remove vehicles from the authorized list
View detection history and export logs to CSV
Monitor detection statistics via charts and analytics
The dashboard is optimized for both desktop and mobile browsers, providing seamless monitoring and control across devices.

1. Functional Module
Each module performed its designated task efficiently, with smooth navigation between modules.
Core functionalities, such as data processing, user management, and system interactions, were executed without errors.

2. Data Handling
The system was capable of securely handling, storing, and retrieving data. Accuracy and integrity of data operations were verified through extensive testing.

3. Performance
The application demonstrated quick response times under varying loads. Optimization techniques applied during development ensured low latency and high throughput.

4. Testing Reports
Successful completion of unit, integration, and system tests. Zero critical defects and minimal minor issues post User Acceptance Testing (UAT).

5. Deployment
The system was deployed with full operational capability. Users reported satisfaction regarding usability, speed, and reliability during the initial deployment phase.

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VI. RESULT

XI. CONCLUSION

In this project, we successfully implemented a custom vehicle license plate detection and recognition system using YOLOv8 and Paddle-OCR. By training YOLOv8 on a custom dataset, the model achieved accurate localization of license plates under diverse real-world conditions. Paddle-OCR was then used to recognize alphanumeric characters from the detected plates, enabling a complete end-to-end solution. The system demonstrated reliable performance on both static images and video frames, proving its effectiveness in real-time scenarios. While the results are promising, future enhancements can focus on improving recognition accuracy for blurred or partially visible plates, supporting multiple regional formats, and optimizing the pipeline for deployment on embedded devices. This work contributes a scalable, efficient, and adaptable solution for automated license plate recognition in intelligent transportation systems.

X. FUTURE SCOPE

The future of vehicle license plate detection and recognition holds significant potential for advancement. Incorporating advanced image enhancement techniques, such as super-resolution, can improve plate clarity under challenging conditions, boosting OCR accuracy. Leveraging YOLOv8's instance segmentation will help detect overlapping or occluded plates, enhancing performance in crowded scenes. Optimizing the system for edge devices will enable real-time processing in surveillance and toll collection applications, supporting smart city infrastructure. Expanding OCR capabilities to handle multiple languages and regional plate formats will increase the system's global applicability. Integration with law enforcement and traffic management databases can facilitate automated violation detection, vehicle tracking, and traffic analytics, improving public safety and urban planning. Implementing continuous learning will allow the system to adapt to new plate designs and environmental changes, ensuring sustained accuracy. Moreover, exploring next-generation detection models, including those using neural architecture search, can further improve detection speed and precision. As the automatic number plate recognition market grows rapidly projected to reach over USD 111 billion by 2032 with a CAGR of 11.9% these advancements will be crucial for meeting increasing demand in traffic management, security, and smart city applications.

XI. CONTRIBUTION

In this project, our major contributions are:

Development of Detection and Recognition Pipeline:

A robust system was designed, integrating YOLOv8 for real-time license plate detection with Paddle-OCR for accurate alphanumeric character recognition, enabling end-to-end automation.

Custom Dataset Collection and Annotation:
A dedicated dataset was curated, encompassing images captured under varying lighting, angles, and plate designs. Manual annotation ensured precise bounding boxes for license plates, enhancing model training.

Optimized Model Training:
Hyperparameters such as learning rate, batch size, and input size were systematically tuned to maximize performance. This optimization led to improved detection accuracy and efficient processing, essential for real-world deployment.

Advanced Preprocessing and Augmentation:
Data normalization and augmentation techniques, including rotation and brightness adjustments, were applied to the dataset. These steps increased the model's resilience to environmental variations and reduced the risk of overfitting.

Seamless OCR Integration:
Detected license plate regions were directly processed by Paddle-OCR, facilitating accurate extraction of alphanumeric information. The approach accommodates diverse plate formats and enhances the overall recognition rate.

Comprehensive Performance Evaluation:
The system was rigorously evaluated using metrics such as precision, recall, mean Average Precision (mAP), and character-level accuracy. This thorough assessment ensures the solution's reliability and effectiveness in practical scenarios.

XII. ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to their project supervisor for invaluable guidance and continuous support throughout the development of this work. Special thanks are extended to the faculty and staff of the Department of Computer Science and Engineering for providing the necessary resources and a conducive research environment. The authors also acknowledge the contributions of their peers and family members for their encouragement and motivation during the course of this project. Finally, the use of open-source tools and publicly available datasets is gratefully recognized, as they were instrumental in the successful completion of this research on vehicle license plate detection and recognition using YOLOv8 and Paddle-OCR.

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