Robust and Unified Vision-Based License Plate Detection and Recognition using Computer Vision

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Abstract - *Smart License Plate Recognition (SLPR) is an important component of modern intelligent transportation systems, enabling automatic vehicle identification for applications such as traffic surveillance, toll processing, and parking control. This project presents a robust vision-based framework for detecting and recognizing license plates in dynamic and real-world environments. The proposed system combines deep learning with computer vision techniques by employing a YOLO version 8 model for real-time license plate detection and PaddleOCR for accurate character recognition. The detection model efficiently locates license plates within images, while the OCR module extracts alphanumeric information even in challenging scenarios, including low illumination, motion blur, and partial occlusions. To evaluate the system, standard performance metrics are used, and the results demonstrate improved accuracy and reliability compared to traditional approaches. The model achieves an overall accuracy of approximately 98%, highlighting its effectiveness and scalability.*

Key Words: License Plate Recognition, Computer Vision, YOLO, OCR, Deep Learning, PaddleOCR.

1. INTRODUCTION

Number plate recognition is a key technology used in several real-world applications, including traffic surveillance, automated toll collection, parking access systems, and stolen vehicle detection. Since each vehicle is associated with a unique license number, it serves as a reliable identifier for tracking and management purposes.

Real-time number plate recognition systems contribute significantly to enforcing traffic regulations by continuously monitoring vehicles on the road. These systems can also be integrated into automated parking solutions, where vehicle entry and exit are managed based on license plate information. Cameras are employed to capture images or video streams, enabling seamless data acquisition without manual intervention.

This project highlights the use of modern computer vision and deep learning techniques for real-time license plate detection and recognition. Specifically, it utilizes a YOLOv8-based object detection model to locate number plates and Optical Character Recognition (OCR) methods to extract textual information. The approach demonstrates an efficient and practical implementation suitable for intelligent transportation applications.

2. LITERATURE SURVEY

License plate recognition is a key component of intelligent transportation systems, where identifying vehicles accurately is essentials for applications such as traffic regulations. Various factors make this task difficult, including changes in lighting conditions, motion blur caused by moving vehicles, partial blocking of license plates, and differences in plate designs across regions. To handle these issues effectively, the system must be capable of adapting to dynamic conditions while maintaining high accuracy and reliability [6]. Based on the level of processing, license plate recognition can be divided into detection and recognition stages, where detection focuses on localizing the plate region and recognition focuses on extracting the alphanumeric characters.

Traditional approaches for license plate recognition mainly rely on image processing techniques such as edge detection, thresholding, morphological operations, and segmentation. These methods are computationally simple but lack robustness and fail to perform effectively under complex environmental conditions. Machine learning-based approaches such as Support Vector Machines (SVM) have been used to improve classification accuracy, but they require manual feature extraction and are limited in handling large-scale data[1].

Recent research has focused on deep learning techniques, which automatically learn feature representations from data. Convolutional Neural Networks (CNNs) are widely used for image-based tasks such as object detection and classification due to their ability to capture spatial features. Advanced object detection models such as YOLO (You Only Look Once) version8 have significantly improved detection speed and accuracy by processing the entire image in a single pass. YOLO-based models are particularly effective for real-time license plate detection. For character recognition, Optical Character Recognition (OCR) techniques are employed to extract text from detected plate regions[3]. Modern frameworks such as PaddleOCR integrate deep learning-based detection and recognition models to achieve high accuracy even in challenging conditions. These models utilize feature extraction and sequence modelling to recognize characters efficiently.

Deep learning has gained significant importance due to advancements in computational power and availability of large datasets. It enables automatic learning of complex patterns without manual intervention and supports supervised, semi-supervised, and unsupervised learning methods[4]. In license plate recognition systems, deep learning-based approaches provide improved accuracy, scalability, and real-time performance compared to traditional methods.

2.1 You Only Look Once

YOLOv8 is the newest state-of-the-art YOLO model can be used for object detection, image classification, and instance segmentation tasks. It delivers strong performance in terms of accuracy, as demonstrated on benchmark datasets like Microsoft COCO and Roboflow100. YOLOv8's architecture is composed of three main parts: the backbone, which is a deep convolutional neural network (CNN) for feature extraction; the neck, which fuses and aggregates features from the backbone at different scales; and the head, which makes the final predictions[2].

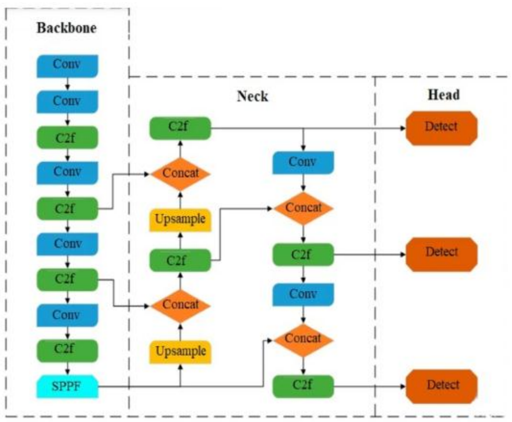

Fig -1: YoloV8 architecture

2.2 Paddle Optical Character Recognition

PaddleOCR is not a single algorithm but an open-source framework or toolkit for Optical Character Recognition (OCR) that integrates a collection of deep learning algorithms. It was developed by Baidu Research and is built on the PaddlePaddle deep learning platform.

PaddleOCR provides a CLI tool for easy text detection and recognition on images and documents. The library is a great option for license plate recognition because of its built-in capabilities, multi-language support, flexibility and sophisticated recognition methods. Optical Character Recognition (OCR) can be applied to the license plate image using paddleOCR once a clear picture of it is taken with a camera or smartphone. Developers can effectively include this feature into their apps because of it swift nature and flexibility

3. PROBLEM STATEMENT

Recent advancements in intelligent transportation and security systems require efficient vehicle identification mechanisms because license plates serve as the primary gateway for identifying vehicles across various applications. This becomes a highly dynamic problem as vehicle images captured in real-world environments are influenced by multiple factors such as lighting conditions, motion blur, camera angles, occlusions, and varying plate formats. These challenges significantly affect the accuracy and reliability of traditional license plate recognition systems. Recent studies indicate that for effective traffic management and law enforcement investigations, it is essential to develop systems that can accurately extract license plate information from images and video streams. In critical scenarios such as police investigations, analyzing surveillance footage and identifying vehicles quickly is crucial for decision-making and security enforcement. This study aims at developing an intelligent system based on deep learning techniques for automatic detection and recognition of vehicle license plates[5]. This work considers the problem of identifying license plate regions and extracting alphanumeric information under diverse environmental conditions. The system is designed to provide accurate and efficient recognition results, thereby improving automation and reliability in traffic monitoring and investigative applications.

3.1 System Architecture

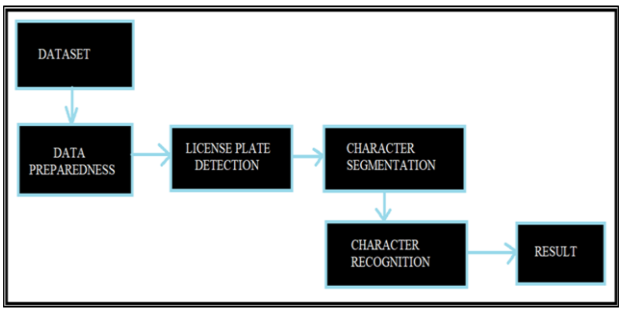

Fig -2: System Architecture

3.2 Dataset Description

The dataset consists of approximately 1,000+ all types of vehicle images which is sourced from kaggle, each labeled with the location of number plates. In the project, after removing the noisy data and unnecessary data the dataset used is almost 1k+ for proper and efficient training. The dataset is split into three parts:

Training Set: 85% of the dataset

Validation Set: 9% of the dataset

Testing Set: 6% of the dataset

The overview of the dataset

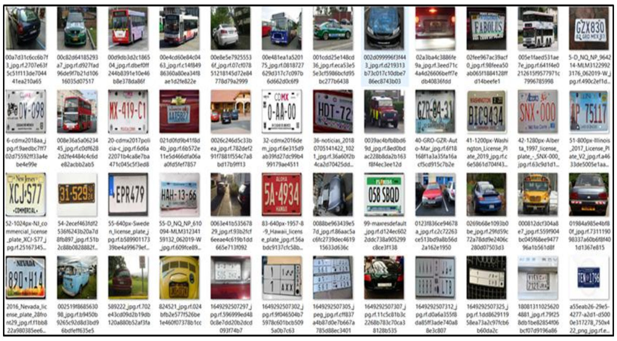

Fig -3: Dataset

3.3 Model Building

YOLOv8 model can observe the entire image at a time and can identify different spatial arrangements of objects within the scene. Different arrangements of visual features such as edges, textures, and shapes may correspond to different objects. An object may lose its identity when these features are not considered together. Consequently, convolutional layers are used for retaining spatial context and extracting meaningful patterns from the image. YOLOv8 utilizes convolutional filters to scan across the width and height of the image, capturing both local and global features. Typical convolution operations process the input image through multiple layers to generate feature maps that highlight important regions.

The pre-processed image data after resizing and normalization is represented as structured pixel arrays. To enable efficient detection, the model learns dense feature representations through deep convolutional layers. The YOLOv8 architecture consists of a backbone for feature extraction, a neck for feature aggregation at multiple scales, and a detection head for predicting bounding boxes and class probabilities. The model processes input images in a single forward pass, enabling real-time detection performance.

For YOLOv8 modelling, the input is a set of annotated images with bounding boxes representing license plate locations. The model is trained using optimization techniques to minimize detection loss, which includes localization and classification errors. Next, once the license plate region is detected, the cropped image is passed to a recognition module.

3.4 Character Recognition and Extraction

After detecting the license plate using the object detection model, the identified region is cropped from the original image. This cropped plate image is then pre-processed using techniques such as resizing, normalization, and noise reduction to improve image quality and readability.

The processed image is passed to the PaddleOCR model, which performs two main steps: text detection and text recognition. In the first step, the model identifies the regions within the image that contain text. In the second step, it analyzes these regions and converts the visual characters into machine-readable text.

PaddleOCR uses deep learning-based feature extraction and sequence modelling to recognize characters accurately, even in challenging conditions such as low lighting, blur, or distorted images. The final output is the extracted alphanumeric sequence representing the license plate number. This workflow ensures efficient and accurate extraction of license plate information for further applications such as traffic monitoring and law enforcement.

3.5 Result

Table -1: Accuracy

Performance	YoloV8 (before FineTune)	YoloV8 (after FineTune)
Accuracy	95%	98%

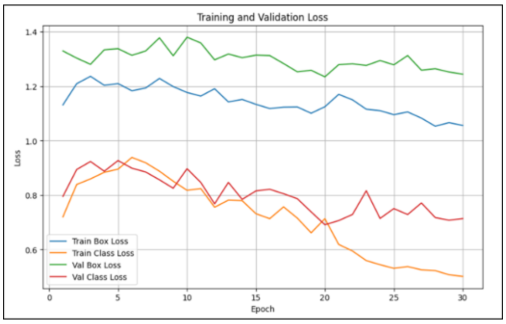

Fig -4: Training and Validation Loss Graph

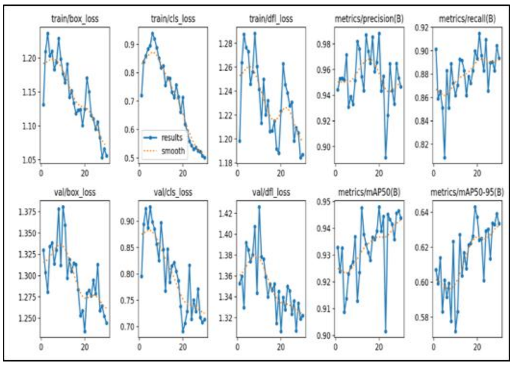

Fig -5: Evaluation metrics Graph

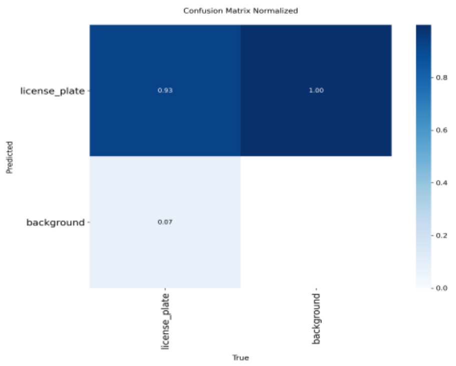

Fig -6: Confusion Matrix

Fig -7: License plate detection

	Filename	Extracted Text
0	c.jpg	GE3425-17
1	DSC_0968.JPG	LEA-061856
2	DSC_0969.JPG	MNA-08 3685
3	DSC_0970.JPG	LWK-5850
4	DSC_0971.JPG	PU18P0L1CE-13VR287
5	DSC_0971x.jpg	MNAA-082206
6	DSC_0973x.jpg	8FM-73151NDH
7	DSC_0975.JPG	LET-5280
8	DSC_0982.JPG	LE8-181194
9	DSC_0984.JPG	LEC-1487
10	DSC_0985.JPG	MN484
11	DSC_0988.JPG	1CTVX-87415LAMA8AD
12	DSC_0990.JPG	MNA-085007
13	DSC_0994.JPG	F5A5750
14	DSC_0996.JPG	8R5121500
15	DSC_0997.JPG	MNA-97486

Fig -8: Extracted Result of Detected Data

4. CONCLUSIONS

This paper presents a robust license plate recognition system using deep learning and computer vision techniques. The integration of object detection and paddleOCR improves accuracy and efficiency in real-world scenarios. The system demonstrates strong performance in dynamic environments and can be effectively used in traffic management and security systems.

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