Vehicle Number Plate Recognition System Using Deep Learning

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Abstract- Vehicle Identification is being done by Vehicle Number Plate Recognition (VNPR) systems in applications such as traffic monitoring, toll collection, and security surveillance. However, many existing VNPR systems are intended for large-scale environments such as toll gates and city-wide monitoring infrastructures. This paper presents a VNPR system which is simple and cost-effective majorly designed for smaller regions such as public parks, institutional campuses, and restricted residential buildings. The system automatically captures vehicle images either from stored input images or through a live camera interface. The detected vehicle images are analysed through image processing techniques to detect the number plate region and extract the characters through a technology called Optical Character Recognition (OCR). In addition, a Convolutional Neural Network (CNN) based deep learning approach is applied to boost the accuracy of character recognition [3]. The recognized vehicle number can further be used for applications such as access control, vehicle monitoring, and maintaining entry records within the premises. The proposed system therefore provides an efficient automated solution for vehicle identification in small and controlled environments while reducing manual effort and improving security [4].

Keywords– Vehicle Number Plate Recognition System, Deep Learning, Image Processing, Computer Vision, Access Control Systems, Smart Surveillance.

1. INTRODUCTION

The development and implementation of an automated Vehicle Number Plate Recognition (VNPR) system capable of detecting and reading vehicle license plates from captured images as well as from images obtained through a live camera interface is the objective of this work. In the proposed system, image processing techniques and OpenCV-based computer vision methods are applied, together with Optical Character Recognition(OCR) to extract the license plate area and identify the alphanumeric characters present on it [1].

The system follows a structured approach consisting of several stages, including visual data manipulation, locating vehicle identifiers, breaking down the characters, and reading textual digits. These stages collectively convert a captured vehicle image into readable textual information.

Image preprocessing techniques such as grayscale conversion, noise removal, and edge detection are used to improve quality of the input images [2]. The preprocessing operations like improving image clarity, highlighting structural features etc increase the efficiency and reliability of the VNPR system

This research demonstrates integration of computer vision and machine learning techniques for automated identification of number plate and thus corresponding information of the vehicle. By automating the license plate recognition process, the system reduces the need for manual monitoring and improves the efficiency, accuracy, and speed of vehicle identification tasks [3]. The system works with both images already stored and images captured in real time through a live camera interface, making it suitable for efficient monitoring in smaller areas.

The scope of the VNPR system also includes the integration of multiple modules into a complete automated recognition framework. This paper presents different techniques that is used to identify the number plate of the vehicles and also explain the methods that are used for character segmentation. It also explains the character recognition process used to identify the alphanumeric characters present on the license plate. In addition, the system architecture and implementation details are discussed by the authors to explain the working of different modules. Finally, the paper concludes with a summary of the developed system and outlines potential future improvements.

2. LITERATURE REVIEW

Vehicle number plate recognition system is use to employ various image processing techniques to spot vehicle number plates and gather the necessary details for identifying the vehicle [4]. In many VNPR systems, the number plate areas is being detected by identifying areas of the vehicle image that contain similar structural patterns and edge densities associated with number plates [5]. However, during the identification of vehicle registration plates, various challenges related to environmental conditions such as lighting variations, complex backgrounds, motion blur, and image noise may affect the detection and recognition performance [6].
Authors in [7] has improved the quality and speed of recognition try to resolve various problems previously encountered in real-world deployments. [8] compares the

different methods or approaches on the basis of their underlying techniques, limitations, strengths and its performance under diverse conditions. Furthermore, the robust deployment of ANPR systems often necessitates consideration of additional hardware to maximize accuracy, given that factors such as number plate condition, non-standardized formats, complex scenes, and environmental variability can undermine performance [9]. Therefore, advancements in image processing techniques along with latest machine learning algorithms, are use to achieve high accuracy and reliability in license plate verification and validation in real time complex scenario [10].

The proposed VNPR system is intended for controlled environments such as residential societies, institutional campuses, parking areas, and public parks where automated vehicle identification can improve security and monitoring efficiency. By implementing automated number plate recognition, the system provides a practical solution for vehicle entry management and intelligent monitoring applications.

3. VEHICLE NUMBER CHARACTERISITICS IN INDIA

Depending on the rules determined by the transport authorities, vehicle number plates have different designs in various countries [11]. In India, vehicle number plates follow standardized guidelines issued by the Ministry of Road Transport and Highways (MoRTH). These rules define the format, dimensions, color combinations, and character specifications used on vehicle registration plates [12].

An Indian vehicle registration number generally composed of four parts:

State Code (two letters) – The first two characters indicate the state or union territory in which the vehicle is registered. (e.g., RJ for Rajasthan, DL for Delhi, MH for Maharashtra).

District Code (two numbers) – The next two digits indicate the Regional Transport Office (RTO) or district where the vehicle was registered.

Series Code (one or two letters) – These letters represent the alphabetical series assigned by the RTO once previous number combinations are exhausted.

Unique Number (four digits) – The final four digits represent the unique identification number of the vehicle [13].

For example, in the registration number RJ14 AB 1234, "RJ" indicates the state Rajasthan, "14" represents the RTO code, "AB" is the series code, and "1234" is the unique vehicle number.

Under the High Security Registration Plate (HSRP) system, the design and look of number plates in India are standardized [14]. According to these regulations, private vehicles display black characters on a white background, while commercial vehicles use black characters on a yellow background. Other categories such as government vehicles, electric vehicles, and diplomatic vehicles may use different color combinations as specified by transport regulations.

Table 1: Standard Dimensions of Vehicle Number Plate Characters in India

Properties	Car	Motorcycle
Character Height	65 mm	35 mm
Character Width	10 mm	7 mm
Character Stroke Thickness	10 mm	5 mm
Space Between Characters	10 mm	5 mm
Space Between Groups	20 mm	10 mm
Plate Thickness	Standard HSRP plate	Standard HSRP plate
Plate Thickness	Standard HSRP plate	Standard HSRP plate

The dimensions and spacing of alphanumeric characters on number plates are standardized to ensure visibility and uniformity across vehicles [15]. These standards define parameters such as character height, character width, stroke thickness, and spacing between characters. Maintaining uniform dimensions helps improve the accuracy of automated license plate recognition systems and ensures that number plates remain readable under various environmental conditions. Several vehicle number plate considerations are shown in Figure 1.

Variants of the number plates	Variants of the environment
Plate size Plate background Plate location Quantity Font Angle Screw	Brightness Similarity in background

Figure 1: Indian vehicle number plate considerations

4. PROPOSED SYSTEM

Registered number plate of vehicles are detected and recognized from digital images and from a live camera feed by the Vehicle Number Plate Recognition (VNPR) system. [16]. The system is proficient in processing both vehicle images stored in memory and images captured in real time through a camera interface.

By integrating a live camera module, vehicle images can be captured continuously and process them automatically for plate detection and recognition. Alphanumeric characters present on the Vehicle number plate are extracted by applying image processing techniques with Optical Character Recognition(OCR) methods.

Automating the number plate recognition process reduces the necessity for manual monitoring and thus improves the effectiveness and accurateness of vehicle identification. For monitoring and access control, the recognized license plate number can be displayed by the system interface and stored in a database.

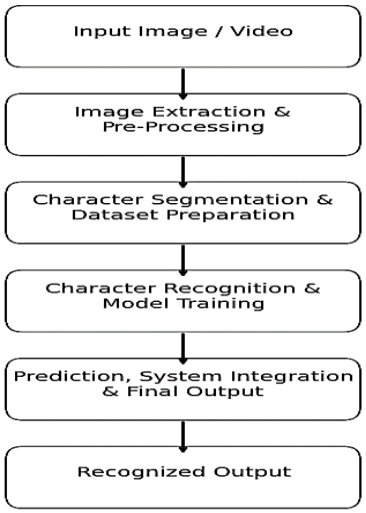

Figure 2: Proposed System

4.1 Module Description

This section describes different modules involved in VNPR System:

4.1.1 Image Extraction and Pre-Processing

The system processes digital images of vehicles with visible license plates; an image extraction and pre-processing module cleans and prepares these images, ready for character segmentation and character recognition. Since raw images may include noise, uneven illumination, or complex backgrounds, preprocessing operations are applied to improve image quality before performing plate detection [17].

Initially, the input vehicle images are loaded into the system and resized to a standardized resolution. Image resizing ensures uniformity across different samples and reduces computational complexity during later processing stages. After resizing, color images are converted into grayscale format. Converting images to grayscale reduces the number of color channels and simplifies the computational tasks while preserving the structural information required for identification of number plate as shown in Figure 3[18].

Noise reduction methods such as Gaussian filtering or median filtering are employed to remove unwanted distortions present in the image. These filtering techniques smooth the image and eliminate differences in pixel values that could compromise with the detection process. In addition to noise reduction, contrast enhancement techniques such as histogram equalization may be used to augment the visibility of important features in the image.

The system first improves the images, then applies methods that make the boundaries between different parts of the vehicle stand out. Since number plates typically contain strong horizontal and vertical edges, edge detection techniques help emphasize the plate region [19]. The processed image generated in this stage serves as the input for the modules dedicated for detection of vehicle number plate and segmentation modules dedicated for character segmentation.

Furthermore, morphological operations are applied to refine the detected edges and remove small irrelevant regions. These operations strengthen important structures while suppressing background noise. Image normalization techniques is applied to maintain consistent intensity values across images which are captured under different lighting conditions.

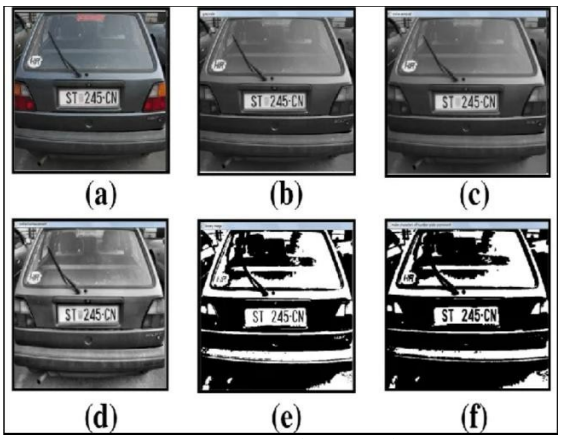

Figure 3: Gray Scale Conversion

4.1.2 Character Segmentation and Dataset Preparation

Once pre-processing and a successful localization of the vehicle number plate region are complete, the characters on the number plate are isolated as the next step. Character segmentation as shown in Figure 4 is most important parts in the VNPR system because the recognition accuracy is largely determined by how effectively the characters are divided from the plate region [20].

In this stage, region of license plate extractedewfrom the vehicle image and processed using segmentation techniques. Thresholding methods are applied to convert the plate region into a binary image in which characters appear as foreground objects while the background becomes a separate region. This binary representation simplifies the identification of individual characters [21]. We then trace the border of every letter or number through contour detection techniques. Each contour corresponding to a character is identified and extracted from the plate region. The segmented characters are cropped individually and resized to a fixed dimension so that they can be processed consistently during recognition. After this, all the extracted characters are arranged into a dataset for training and testing the recognition model. Each character image is stored under its correct label, such as numbers (0–9) or letters (A–Z), which helps the model learn and recognize different patterns effectively. To make the database more diverse, extra data is artificially created by doing things like rotating sketches, scaling, or adding noise. These operations improve the ability of the recognition system to correctly recognize characters under different

environmental conditions such as lighting variations, slight rotations, or partial distortions [22].

Furthermore, normalization techniques are applied to ensure that all segmented characters maintain consistent size and pixel intensity values. This helps the recognition model process each character uniformly during both training and testing. Proper segmentation and dataset preparation significantly influence the final operation of the VNPR system where as separated and clearly labelled characters allow the model to accurately learn distinguishing features of alphabets and digits.

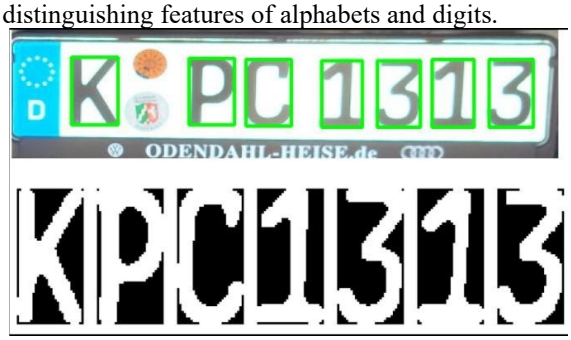

Figure 4: Character Segmentation

4.1.3 Character Recognition and Model Training

The character recognition module identifies the alphanumeric characters extracted from the segmented license plate images. The segmented character images are transformed into machine-readable text by applying pattern recognition techniques like OCR, in combination with machine learning approaches like Convolutional Neural Networks (CNN) [23]. The proposed CNN model processes 28×28 grayscale images using three convolutional layers (32, 64, and 128 filters) with ReLU activation, batch normalization, and max-pooling for effective feature extraction. The network is followed by fully connected layers with dropout regularization and a softmax output for multi-class classification. Training is performed using the Adam optimizer with categorical crossentropy loss, supported by data augmentation and class balancing to enhance generalization and robustness. In the training process, the prepared dataset of segmented characters is taken to train the recognition model. The model learns structural patterns and visual features associated with each character. Feature extraction techniques may be applied to capture relevant information such as character shape, edge structures, and pixel intensity distributions. Using this information, the model is trained with labeled data, meaning it already knows the correct answer for each image. As it learns, it keeps improving by adjusting itself to make more accurate predictions, while we monitor its performance through accuracy and loss. After the training phase is completed, the model is validated using test data to measure its ability to recognize characters from previously unseen images. Any misclassifications are analysed and improvements are made to the training process for improving recognition accuracy. The trained recognition model can then be used to identify characters extracted from new license plate images and turned them into digital text [24].

The trained recognition model can then be used to identify characters extracted from new license plate images and turned them into digital text [25] as shown in Figure 5. The dataset used [24] comprises 36 classes (digits 0–9 and alphabets A–Z) derived from MNIST and handwritten character datasets, with 28×28 grayscale images organized in labeled directories. Preprocessing includes resizing, normalization, segmentation using OpenCV, and noise reduction to enhance data quality. The processed dataset is split into training and validation sets to ensure reliable model performance evaluation.

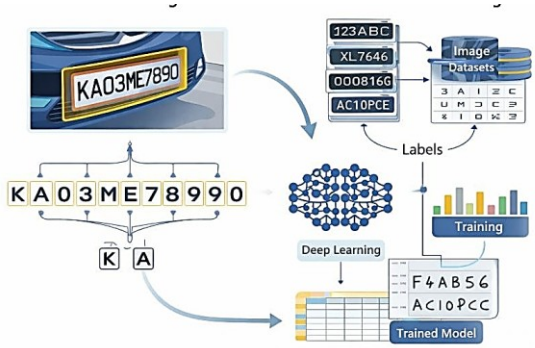

Figure 5: Character Recognition

4.1.4 Prediction, System Integration and Final Output

The prediction and system integration module combines all previously developed components into a complete VNPR system. In this stage, to make the whole process automated, the trained recognition model is joined together with the system's pre-processing, license plate detection, and character segmentation modules [26]. This integration ensures that all modules operate sequentially and efficiently to produce accurate results. When a new vehicle image is given to the system, it is first cleaned and enhanced using preprocessing techniques like converting it to grayscale, removing noise, and improving contrast. This helps make the image clearer. Next, the system locates the number plate area within the image using detection methods. Once the plate is identified, it is extracted from the image. After that, the characters on the number plate are separated using segmentation techniques. Each letter and number is isolated and converted into an individual image so that it can be easily analyzed by the recognition system. The segmented character images are processed by the trained recognition model, and each character's identity is predicted. OCR and machine learning methods are used to analyze the shapes and patterns of each character and map them with the correct characters [27]. As the characters are recognized, they are arranged in the correct order to form the correct vehicle number. This final number is then displayed on the system for easy verification.

Training Accuracy of the proposed model is ~92% and Validation Accuracy is ~90% Loss is Gradually reduced during training due to adaptive learning rate

So The model performs well on most characters. Minor misclassifications occur between visually similar characters such as O and 0 and B and 8

The detected number can also be stored in a database along with details like date, time, location, or user information, which helps in record-keeping and tracking authorized vehicles as shown in Figure 6.

Other than this, the system can be improved further by adding features like real-time recognition, connecting it with surveillance systems, and enabling automatic logging of vehicle entries.

With further improvements in image enhancing methods and models, the accuracy and reliability of the VNPR system can be enhanced to support more advanced transportation and monitoring applications [28].

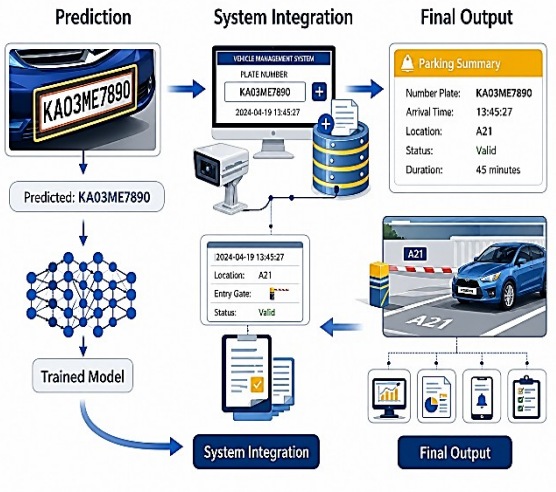

Figure 6: Prediction and Final Output

5. CONCLUSION

As part of this research, a system for automatically detecting and recognizing vehicle registration numbers has been developed. This system works with both digital images and live camera feeds. The major objective of this system is to find an solution that automatically identify number plate of any vehicle using image processing and machine learning techniques in smaller areas like restricted residential societies, etc. The developed VNPR system shows the effectiveness of combining image processing techniques with machine learning models for automatic vehicle identification. The inclusion of a live camera module allows the system to capture vehicle images in real time and perform number plate recognition automatically. The system is able to detect and recognize license plates from different images of vehicle with satisfactory accuracy under normal conditions. By combining preprocessing, detection, segmentation, recognition, and prediction modules, the above approach provides a complete automated solution for identifying as well as recognizing number plate of different vehicles.

6. FUTURE SCOPE

Although the above described Vehicle Number Plate Recognition (VNPR) system demonstrates effective performance in detecting and recognizing vehicle license number plates, there are several possibilities for further improvements and extensions. Future work may focus to improve the overall accuracy, efficiency, and real-time performance of the system when deployed in more complex and dynamic environments which can be done by using some sophisticated techniques [29].

The future development of the proposed VNPR system focuses on improving recognition accuracy, enabling real-time detection through live camera integration, increasing robustness under challenging environmental conditions, and integrating the system with advanced monitoring and transportation infrastructures. These improvements can significantly enhance the reliability, scalability, and practical usability of the VNPR system for many real-world applications. Such systems could assist in identifying unauthorized vehicles, detecting stolen vehicles, monitoring traffic violations, and improving overall transportation management in urban environments.

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