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Exploring Vehicle Number Plate Detection Methods: Yolo Models and Neural Network Models with Different Datasets

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Abstract: - Automatic vehicle number plate recognition (ANPR) is a significant traffic management solution that uses computer vision and deep learning techniques. With the rapid rise in vehicular traffic volumes worldwide, effective traffic monitoring systems have become imperative from safety and administrative perspectives. ANPR systems aim to automatically identify vehicle registration numbers regardless of changing light conditions. At the toll plazas and city entrances, ANPR assists with electronic toll collection and tracking vehicles moving in and out. It can also help with efficient parking management in congested urban areas. The core technical aspects involved are number plate detection (NPD) from images/videos captured by cameras, character segmentation to isolate the plate region, and optical character recognition (OCR) to read the alphanumeric characters accurately. State-of-the-art deep learning models like YOLOv7, CNN, LSTM networks and YOLOv5 are evaluated for their ability to detect plates under different circumstances. An infrared sensor facilitates clear number plate captures under varying light intensities. The overarching goal is to develop a robust ANPR framework through computer vision and deep learning for diverse traffic analytics and regulatory needs. The experiment result analysis of different deep learning models helps identify the best solution.

Keywords*: Deep learning, OCR, Number plate detection models, YOLOv7, CNN, LSTM and Yolov5.*

1. Introduction

Nowadays, with the development of technology, the demand for traffic control and monitoring grows in conjunction with the frequency of vehicles on the roads. Machine learning and image processing are currently utilized by computers to monitor transportation. Counting vehicles on highways, parking penalty warnings, handling databases, blacklisting and lost vehicle notifications, etc. are just a few of the complicated jobs it completes while also saving labor. It takes a lot of effort and time to manage transportation and automobiles. If it is fully manually activated, this shows colossal faults and challenges. So, the development of an automatic vehicle number plate recognition system is required. Domestic parking spots are required more and more as a result of a profession-driven approach to management. The majority of people on earth live in cities, where they need safe, convenient parking spaces to utilize every day [1]. The development of intelligent transportation systems has been accelerated by the building of technologically advanced cities, and license plate recognition structures are an essential feature of such networks. These systems perform a necessary twenty-six practical roles in enhancing traffic effectiveness, law enforcement, and road safety. A major challenge for relevant researchers to address is how to better the precision and real-time functionality of the number plate identification system under a range of difficult instances. Numerous academics carried out in-depth studies on NP recognition [2]. The owner information for the allowed car registered in the parking management system is also recorded in this system. Real-time data indicating the entrance or exit of the vehicles will be triggered each time they enter or leave the parking IoT.

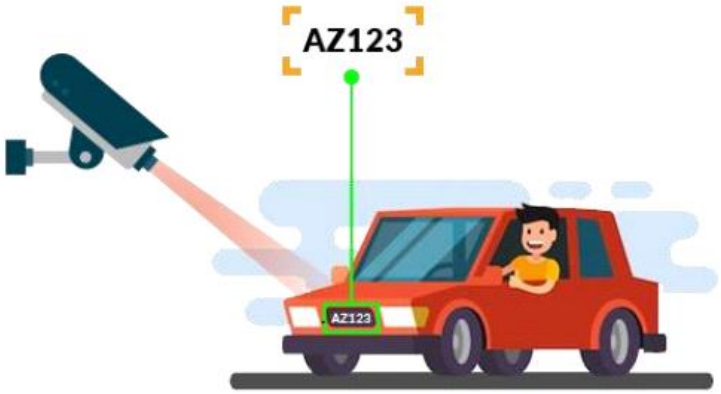

Fig. 1 Example of Number Plate Detection

Automatic license plate recognition (ALPR) is commonly utilized to minimize accidents and parking offenses, and boost vehicle electronic ticketing choices. A license plate is a vital identifier given to the government for tracking and recognizing automobiles. License plates are used by traffic wardens, revenue agents, and other stockholders to monitor traffic and store records accordingly. Spontaneous monitoring systems based on computer vision and ML methods are a major component of contemporary traffic management systems [3]. The automatic number plate or car registration plate detection is other names for the same thing. It extracts the license plate from digital snapshots or video recorder using image processing methods. Fig 1 represents the example of number plate detection. Following that, new models can be discovered using the information that was previously collected; these new models may include transaction gateways or systems for tracking traffic damages. In practical uses, researchers must contend with a variety of difficulties, including the type of license plate, the text's font and color, the location of the plate, and a variety of environmental factors like weather and lighting. All of these factors must be taken into account in the context of a real-world problem. It becomes more difficult to identify license plates. Different colors, languages, and fonts are used on license plates in different countries [4]. A few license plates have borders that are a different color than the background they are on, while others have a plain background, which makes it more difficult to photograph and identify license plates. The degree to which license plates may be recognized varies depending on ambient factors including illumination and image background. The number plate imageries are acquired from the captured images using a camera or the necessary dataset as part of the number plate recognition detection procedure. An alpha-numeric conversion of the acquired images into a text input is achieved by processing in two ways still images or digital

video through a number of image processing-based recognition algorithms. Any ANPR system's main reliance, after capturing an excellent image of the environment or vehicle, is on how reliable its mathematical models are. To achieve the desired outcomes and address all system complexity, these algorithms necessitate thousands of lines of software coding [1]. For smart car technology like ANPR to function properly, a collection of fundamental algorithms is required. So, the detection process follows image acquisition, pre-processing, enhancement, filtration, image processing, thresholding, segmentation and character recognition etc. An automatic detection of number system face some challenges as well as limitation due to insufficient signal resolution. Sometimes due to the utilization of a black and white camera although mainly because the plate is located too far away. Illustrations that are distorted, particularly when moving. A combination of repeated exposure and dark reflection, the picture's illumination is inadequate and the level of contrast is low. AA pulling bar, as well as which happens to be often the case, or dirt on the license plate. Take a look at license plates that have different data printed on the front and back due to towing vehicles, campers, etc.

When detecting plates, the sensor's field perspective fluctuates due to variations in the traffic lane. An unusual font that is used for vanity plates. Insufficient cooperation across nations or communities. The identical number but an individual pate layout could be found on two vehicles from separate nations or states [5]. Various experts

focused on number plate detection for improvement such as **V Gnanaprakash et al. [6]** developed vehicle detection tool by using R-CNN and rapid R-CNN. These models were utilized for testing and training in three phases such as data achievement, RNN and CNN scheme. They reached around 94.98% of overall performance accuracy. **Md. Atikuzzaman et al. [7]** developed a model by using digital images, pre-processing, feature extraction and filtration etc. They also deployed Python language and Cv2 opens library and tesseract intended for character detection. **Yujie Liu et al. [8]** presented identifies color edges with the help of morphological detection, extraction for number plate. Projection analysis and CCA using fixed dimensions, subdivision characters which are monitored using recognition and CNN method. **Jiafan Zhuang et al. [9]** utilized semantic segmentation used semantic segmentation as well as including improvement for number plate detection. This technique mechanism designed for fixed-length number plates and be unsuccessful for variable measurements. India has a different set of ANPR requirements than other nations due to its population of 1 billion individuals. Highway surveillance, parking supervision, and local criminal justice security are three areas where ANPR is most commonly used. In India, there is one death each four a few minutes, the majority of which are caused by careless driving. ANPR is used to track the standard velocity of the moving traffic and can spot over-the-limit vehicles. By determining the distance between both of the cameras, a fine ticket can be created automatically in this situation.

As a result, there may be fewer accidents on the roads if rules and regulations are preserved. For administering parking, ANPR offers the greatest option. Parking spaces are open to vehicles with registered license plates without charge during check-in and check-out; however non-registered vehicles must pay to park. Annual car theft in India totals twenty thousand. If the right measures are implemented and the ANPR system is utilized to track automobiles, this number can be reduced. That way, if vehicles are stolen, law enforcement will be able to determine what happened, where, and the path travelled by the vehicle that was stolen. This can assist in rapidly bringing justice to such a large country.

This paper organizes as: section 2 includes literature survey of various existing methods, process of number plate detection in section 3. OCR methods and their advantages and disadvantages consist of section four. Section five includes process of number plate detection process and six consist of conclusion.

2. Related Work

Yash Shambharkar et al., (2023) [4] described automatic number plate detection technology has become more prevalent in the fields of security, safety, and commerce. Computer vision is used to detect and recognize license plate numbers quickly and accurately. Using either Deep Learning (DL) methodology, numerous computational methods have recently been created for the recognition of car registration based on NP detection. In the suggested model, ANPD and recognition was achieved using OCR and a novel DL-based technique. That was trained to recognize the car using a DL method. A CNN works OCR to recognize numerals and letters after a sufficient cropping of the image's automobile registration plate region. The proposed model was evaluated by using the Kaggle dataset, with the Jetson TX2 NVIDIA target serving as the source of training data. The highest accuracy could find was 96.23%. The implemented method could identify car license plate numbers (LPNs). The technology could be used at security checkpoint gates in extremely controlled regions. **Umair Yousaf et al., (2021) [10]** described recognition of classifying the text within the bounding box, LP localization was the procedure of locating the license plate area and drawing a bounding box around it. Modern methods for LP localization and recognition need that license plates have standardized dimensions, designs, fonts, and colors. Regrettably, license plates in Pakistan separated in terms of the aforementioned features and are not uniform. In order to localize and detect Pakistani license plates with irregular and non-standard sizes, typefaces, and styles, this study introduces a DL-based technique. In order to train and test the suggested model, we created a brand-new dataset of Pakistani LP. It compared the performance metric such as accuracy of the proposed model with other methods, they performed wide-ranging trials. The outcomes of the suggested method were delivering very well. **Chao Xu et al., (2020) [11]** described the rapidly domain of artificial intelligence (AI). Particular repetitive automated traditional acts were progressively swapped by AI. Recognition of license plate was a standard instance which deployed DL facts to reality. But, many LP recognition approaches were restricted to attain the license

plate, rather than discovering the license plate data. License plate OCR was considered as a procedure of an operational recognition of Chinese words, and numbers according to the accurate license plate detection process. **V. Gnanaprakash et al., (2021) [6]** described the growth of technologies and a secure way of living and traveling are in high demand among people in this era of rapidly evolving technology. The great growth of the automotive industry made tracking specific automobiles of an extremely hard operation. With the use of security cameras placed along the road, the authors developed an automatic vehicle monitoring model for rapid cars. Procurement CCTV data with real-time contextual was a highly difficult task. An effective DL model such as YOLO model was utilized for object detection and to address this issue. They utilized 4 fundamental phases to identify from each frame of the video in the first phase, which consists of turning the video footage into images. The next phase was the detection of license plates from the identified autos. The characters of number plate were recognized from the observed number plates in the previous phase. The proposed DL model was required an Image library for training purpose. Images of Tamil Nadu license plates were consumed for the model's performance evaluation. The performance of the proposed model was reached as accuracy 97%, 98% and 90% for car detection, number plate localization and character recognition respectively. **Shan Luo et al., (2022) [12]** developed a car LPR technique based on improved YOLOv5m and LPRNet model. They deployed a YOLOv5m method was improved by using three factors and improves the car license plate features. LPRNet network model was utilized to appreciate the word detection, and segmentation of LP. Hybridization of the improved YOLOv5m and LPRNet network, a LPR model based on IYOLOv5m-LPRNet model was developed. The simulation analysis of the proposed model was improve the average detection performance of license plates and reached more than 98% of performance. This proposed model was compared with exiting five YOLO models and offers better speed and robustness. **Asli Gode et al., (2023) [13]** constructed a LPRS model to offers mechanism and security. These models were developed with AI, ML, ANN, DL, fuzzy logic, adapted models, and image processing. The authors developed an LPRS model by using AI and image processing methods. Hardware formation of the proposed was built by using Raspberry Pi 4 Single-Board Computer (SBC). The major motive of the proposed model was to develop an LPRS using AI and image processing methods. They deployed the implementation process of the process model into a three parts such region detection, grayscale conversion, masking process. At last, the pytesseract method was required to identify license word.

Table I consists of analysis of various existing number plate detection methods, tools, problems and performance parameters.

TABLE I: COMPARATIVE ANALYSIS

Year, Author Name	Title	Proposed work	Dataset	Problem	Tool	Parameters
Yash Shambharkar et al. (2023) [4]	An Automatic Framework for Number Plate Detection using OCR and Deep Learning Approach	CNN	Kaggle database.	Lack of multi languagistic applications	Python	Accuracy
V. Gnanaprakash et al. (2021) [6]	Automatic number plate recognition using deep learning	YOLO model	Kaggle dataset	Limited accomplishment of CCTV shots in the real-time.	IMAGEAI	Accuracy

Umair Yousaf et al. (2021) [10]	A Deep Learning Based Approach for Localization and Recognition of Pakistani Vehicle License Plates	LSTM	Pakistani license plate dataset (PLPD)	Only implemented on specified language based number plates.	*	Accuracy Recall Precision F1 Score
Chao Xu et al. (2020) [11]	License Plate Recognition System Based on Deep Learning	SVM	Captured images	Static shooting domain only detects particular area of park License Plate.	OPEN CV	Accuracy
Shan Luo et al. (2022) [12]	Research on Car License Plate Recognition Based on Improved YOLOv5m and LPRNet	IYOLOv5m-LPRNet	Chinese City Parking Dataset	Required massive dataset for detection process implementation.	Python 3.8, 331 CUDA 11.6, CuDNN 7.6	Recall Precision F1 Score map
Asli Gode et al., (2023) [13]	License Plate Recognition System Based on Artificial Intelligence with Different Approach	AI model Bilateral and canny filtering	110 vehicle image	This method is not suitable in case of large dataset. Deficit to detect number plates night time.	Python Opencv, NumPy, imutils	Asli Gode et al., (2023) [13]

3. Number Plate Detection Structure

Image processing, extraction, and segmentation technology are needed for number plate recognition. The output should be clear after using a camera to capture the photographs or video. The number plate detection structure in figure 2 consists of basic fundamental steps: An image or video that has been recorded by the camera is used as input in the first phase. The video is then divided into frames, and a clean frame or image is chosen from those. The portion of the metal surface is subsequently extracted using two features, including aspect ratio and edge density. On the license plate, segmentation is employed to separate and distinguish each number. To properly identify the letters and numbers in the correct manner, recognition is eventually applied to the LP. The segmentation of the larger image is finished. It allows the plate's digits to be reached individually. OCR-based template matching is used in segmentation. Finally, the numbers are enhanced to produce a better-preferred image. For the output to be of the best possible standard, the camera has to offer an extremely high resolution.

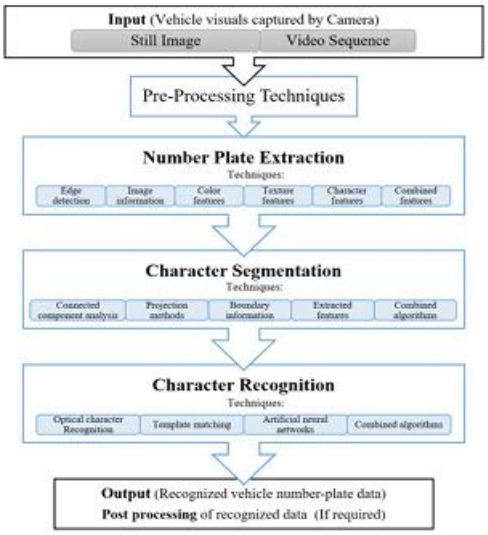

Fig. 2 Number Plate Detection Structure [14]

• *Image Acquisition:* Analogy or digital imaging devices are only two of the examples among a number of techniques that are utilized to enter an image into a system.

• *Pre-processing:* It is the essential phases for every computer vision system are image pre-processing. Therefore, the primary goal of this picture pre-processing is to determine the images and accumulate data about them that can be used in subsequent processing. A non-figurative object's functionality is altered by the image pre-processing procedure [4]

• *Number plate Extraction:* The background also appears once the number plate is captured. As a result, locating the license plate's area is the following procedure. A pair of characteristics is recognized to identify whether the retrieved image is a number plate or not: a) Aspect ratio, which is the proportion of a region's thickness to its depth. It has been employed to calculate the object's region's dimensions, width, height, and area. The other is edge density; even after applying the aforementioned features, some regions are still present. So the local variance derived from the plate region is quantized using edge detection.

• *Character Segmentation:* The number plate has been split into parts like this, and each number is identified. When elements like enlightenment depict noise, etc. have been included, it becomes challenging [15].

Character Recognition: The license plate has been extracted, the final output images manually compared with the input images.

4. Optical Character Recognition (OCR) Recognition

Optical Character Recognition is different from the ideas or words "character recognition" and "optical." Whatever has to do with light or vision is referred to as an optical means. The most excellent instance of an optical device is a computer mouse that employs optical technology. To determine the direction the mouse is traveling across a surface, a LED and light-emitting have been employed. OCR allows for simple for a human to look at the contents of a real image. Because the text is provided in a speech, we can easily and quickly distinguish the text from an image. However, computers don't operate the same way as people to ensure [16]. They are able to read arranged text, which is where OCR enters the picture. It is the electrical conversion of captures into text that has been machine-coded. It is widely utilized to digitize printed text so that it can be changed digitally, maintained with greater accuracy, and shown online [17]. Some of advantages and disadvantages of are described in Table 2.

Table 2. Advantages And Disadvantages Of Ocr Method [17] [18]

Sr. no.	Advantages	Disadvantages
1.	The time and money spent on manually entering the data into the computer will be significantly decreased.	Expensive cost high.
2.	OCR could clear up large amounts of the office space that stacks of paper documents previously occupied.	Superiority of the crucial image based on value of the initial image.
3.	OCR is an innovation that boosts the flexibility of the activities of business. Transform such transferrable files into text-editable documents.	It works accurately on printed text images.
4.	You are able to look for frozen information through the use of OCR technology to convert the content into readable data.	Required more space for image production.
5.	Prevents the chances of human errors.	All the papers acquired to be checked over with judgment then manually modified.

5. Number Plate Detection Methods

Deep learning (DL) is an important module of data science, together with information and analytical models. It aids data researchers accumulate, analyze, and interpret the data. DL methods make this development faster and informal. YOLO is a standardized object recognition tool. In contrast to classifier-based methods, the YOLO technique is presented with a loss function that straightforward relates to detection performance, and the complete model is generated at once. Other one is CNN and LSTM methods are also includes. So, DL is also defined as the way to mechanize diagnostic analytics. Table 3 discussed related detection method advantages and disadvantages. Some of DL methods are described in details as;

A. YoloV7

The YOLO approach's newest version, YOLOv7, evolved in order to boost its efficiency and precision from previous iterations. It handles various object scales using a Spatial Pyramid Network (SPP) and has a more effective architecture with fewer parameters. Paddle OCR is an OCR toolbox based on deep learning, while YOLOv7 is a state-of-the-art object identification model that can precisely recognize objects in an image [19].

B. *Yolo v5*

A few weeks ago YOLOv4 came out, and Glenn and his team of researchers unveiled YOLOv5, an updated version of the YOLO family. In contrast to earlier versions, YOLOv5 uses PyTorch rather than Darknet, according to Nepal and Eslamiat (2022). It makes use of CSPDarknet53 as a backbone. To increase the flow of information, it leverages the Path Aggregation Network (PANet) as a neck. The new feature pyramid network (FPN) that PANet uses has both top-down and bottom-up layers. This enhances how low-level features in the model are propagated. The localization accuracy of the item is improved by PANet because it improves localization in lower layers. Additionally, the head in YOLOv5 is the same as with YOLOv4 and YOLOv3, which provide three separate feature outputs [20] [21].

C. CNN

One of the greatest efficient deep learning models utilized for picture the identification is the CNN model, which is capable of gathering selective pattern features from an enormous amount of data. This scheme's capacity for recognition is essentially human when a significant quantity of data is applied [22] [4].

D. Long-Short-Term Memory (LSTM)

The numbers and letters from a scanned number plate have been identified using the LSTM strategy. An optical character recognition method is this LSTM procedure to get the vehicle's information; the verified number is connected to the series of numbers in the data base [23].

Table 3: Detection Methods: Advantages And Disadvantages

Method Name	Advantages	Disadvantages
YOLOv 5	Fast and simplest for implementation.	Expensive cost high and still considered as under development form...
YOLOv7	Running and implementation of this model is very well.	No suitable for an accurate detection of an object. This method is not detects v various detection of sn images.
CNN	No need human's supervision and reduces the computational time.	Required massive dataset.
LSTM	This model is very well for long term dependencies.	Required more execution time.

Table 4 shows the performance analysis of deep learning methods based on accuracy. According to this analysis YOLOv7 shows an accurate performance as 97% as compared to other methods.

Table 4. Performance analysis

Method Name	Accuracy
YOLOv7 [19]	97%
YOLOv5 [21]	95%
CNN [4]	94.9%
LSTM [10]	89%

Accuracy: it is defined as sum of true prediction (TP) and false negative (FN) prediction divided by total sum of TP, FN, and false positive (FP) and true negative (TN) prediction values.

6. Conclusion

Previous research on Automatic Number Plate Recognition (ANPR) systems found that several models achieved sub-optimal plate detection accuracy under varying real-world conditions. To address this, the proposed approach leverages high-resolution camera technology to acquire high-quality vehicle photos, essential for robust ANPR performance. The system has the capability to capture images of moving vehicles and subsequently localize their number plates through built-in image pre-processing steps. A review of existing ANPR methods revealed limitations in accuracy and effectiveness for many contemporary solutions. This study aimed to evaluate state-of-the-art Dl-based object detection architectures for the tasks of plate localization and OCR. Models like YOLOv7, YOLOv5 and other neural networks were analyzed and their prediction abilities systematically tested. Results showed that among the models evaluated, YOLOv7 achieved the highest accuracy of 97% for end-to-end ANPR, significantly outperforming alternatives. The proposed framework demonstrates the viability of leveraging powerful deep learning object detection models to enhance number plate recognition rates under real-world traffic scenarios, with potential applications in areas like automatic tolling and traffic law enforcement.

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