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Vehicle Number Plate Identification and Recognition of Number Plate Using Deep Learning Based on Approaches in Images and Videos

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ABSTRACT

Automated systems for identifying vehicle number plates are crucial for law enforcement and traffic management tasks. This paper introduces an innovative method that uses deep learning to recognize number plates from images and videos. The process involves detecting number plates using OpenCV's contour detection and approxPolyDP algorithm, followed by cropping and optical character recognition (OCR) using the EasyOCR library. Integration of deep learning models improves accuracy and efficiency. Through a thorough literature review, we highlight the limitations of traditional methods and emphasize the need for advanced deep-learning approaches. Our proposed method addresses these limitations by leveraging deep learning to enhance accuracy and robustness. We provide detailed implementation steps in Python and experimental results demonstrating high accuracy in number plate detection and OCR. Analyzing results, we identify strengths and weaknesses and suggest further improvement. This research contributes to advancing automated number plate recognition systems, promising improved efficiency and accuracy in various domains like law enforcement and security surveillance.

Keywords: Number plate, easyOCR, Deep Learning Model, OpenCV

I. INTRODUCTION

In the contemporary era of technological breakthroughs and fast development of artificial intelligence, growth in automated systems for many applications is at the helm. The most important of these applications include detecting the number plate and recognizing the vehicle for law enforcement, traffic management, and security surveillance. In the traditional approach of number plate recognition, the intervention had often been a manual intervention or through elementary algorithms showing a predisposition toward causing errors and inefficiencies. However, with time, growth, and development of technology, the same applies to the field of computer vision. Some of the techniques introduced are deep learning and have brought about a paradigm shift to very advanced and accurate approaches to automated number plate identification and recognition.

This paper's major aim is to explore deep-learning-based techniques for finding and recognizing the vehicle's number plate through image and video processing. In this project, a system with state-of-the-art deep learning and computer vision must be designed to give a robust and efficient system with high accuracy in detecting and recognizing number plates under different environmental conditions and scenarios.

Accuracy is sensitive in some of the applications to be carried out. Automated number plate recognition systems are very sensitive; they cannot be taken lightly, particularly with the current innovative trends in law enforcement and security surveillance. Rapid and accurate vehicle identification from their number plates has almost become necessary for some tasks with an increasing number of cars and vehicles on all roads and highways worldwide. These include traffic monitoring,

toll collection, and criminal investigations. Traditional manual methods of plate number recognition are labor and time-consuming and, in fact, prone to errors in practice. Besides, these methods cannot scale well with vehicles added onto roads. Thus, automated systems must carry out number plate identification and recognition with high accuracy and speed.

The recent astonishing success of deep learning models in solving some problems in computer vision underlines the great promise with which deep learning endows the machined ability to learn complex patterns and features directly from raw data. Its most significant role has been felt in the revolution of image processing tasks, especially through the capability to automatically extract hierarchical representations in the images, thus simplifying tasks related to object detection, classification, and segmentation. Deep learning approaches have many advantages and edges over traditional or basic approaches when deployed or used in automatic number plate recognition. This is an inborn ability to deal with occlusion, viewpoint, and illumination variations, thus making them more robust for application to real-world scenarios.

This paper's proposed approach comprises several critical constituents, each of which plays a critical role within the overall system architecture. The first stage, detecting the number plates from the input images or video frames, is done using contour detection techniques, in which the OpenCV contour detection algorithm and the approxPolyDP method are applied. The first part wants to locate these areas of interest that hold the number plates within the input data. The regions containing plates are then extracted from the original number plate images or frames for further processing.

After the detection stage, the extracted number plate regions are preprocessed to enhance image quality and reduce noise. Such preprocessing may involve resizing, normalization, histogram equalization, and noise reduction. Preprocessing input data to bring it to an optimum state for use in subsequent tasks (e.g., in optical character recognition (OCR)) bears so much importance because the data analysis techniques involved critically depend on the quality of the input.

The crucial part of the proposed methodology is the optical character recognition (OCR) module, which was developed to recognize and extract alphanumeric characters from the detected regions of the number plates. In this paper, we use the EasyOCR library, one of the most powerful and easy-to-use libraries in the field of OCR. EasyOCR supports more than 60 languages and excellently deals with most tasks of recognizing characters with high precision. After all preprocessing steps, the segmented number plate images are given to an OCR module for alphanumeric value prediction. When integrated with the number plate recognition pipeline, such deep learning techniques enhance the system's accuracy and robustness to handle complex scenarios and input data variations. The approach also facilitates integrating deep learning models pre-trained on large datasets to learn more discriminative features and patterns specific to the number plate images, improving the overall recognition performance.

This paper presents a novel mechanism based on deep learning techniques that can help identify and recognize the vehicle number plate. Systematic exploration of the proposed methodology manifests our approach as effective and efficient for accurately detecting and recognizing. The next sections of the paper elaborate on the methodology, results obtained through experimentation, and discussion, giving insights into the strengths and limitations of the proposed approach and what it implicates for practical applications in different domains.

II. Literature Reviews

This research suggests a roadside surveillance camera-equipped autonomous vehicle monitoring system. License plate recognition systems manage residential access and collect tolls and parking fees in smart cities. Management may obtain secure and efficient services, enhancing people's lives using these technologies. The suggested method recognizes automobile license plates well. Number plates with noisy, poorly lighted, cross-angled, non-standard typefaces can be managed utilizing the method. This research introduces automated License Plate Recognition (ALPR), a robust deep learning system that employs character segmentation and a CNN-based

recognition model. Experimental findings yield 94.94% f1 score accuracy. [1]

The control and surveillance systems rely significantly on vehicle recognition. The blend of letters and numbers on car license plates makes them instantly recognizable. People must work hard to recognize all parked or passing car number plates manually. This study used training to recognize license plates. Automatic number plate recognition (ANPR) systems have been studied in limited situations, such as interior locations, driveways, fixed illumination, and static backdrops. The main goal is to develop a reliable number plate identification model in different lighting situations and angles. Trained YOLO V3 recognition model using manually collected car license plates. The algorithm was tested with 640 pictures of various hues and lighting.[2]

This research presents a machine-learning technique for Indian vehicle number plate detection. To detect Indian car license plates using deep learning. The total epochs and splits proposed a system. The exploratory study shows that our method can analyze key journal results. This study employed several weight maps to find automobile number plates in cloudy settings and extract characters. Again, it proposed utilizing the pre-trained AlexNet deep learning system to improve character extraction. This chapter accomplished the following: To build a phony car number plate detection method. The goal is to use a fog image classification design approach. This study suggests machine learning for Indian vehicle number plate detection. To recognize Indian motorcar license plates using deep learning. The number of epochs and splits determined the proposed system. Exploratory study shows that our method can analyze key journal results. [3]

In this fast-changing technology world, efficient mobility options and enhanced safety are needed more than ever. Due to the exponential rise in cars over the previous decade, monitoring individual vehicles has gotten harder. This study introduces strategic security camera-based autonomous vehicle monitoring. Since real-time CCTV data access is cumbersome, this work uses the You Only Look Once (YOLO) architecture, a sophisticated deep-learning model for object detection. The video is first turned to stills. Next, each still image's automobiles are identified. First of four main steps in the suggested approach. Next, identify the found automobiles' license plates and interpret their characters. The Image AI package simplifies deep learning model training. This comprehensive strategy tackles traffic management and security issues the rising automotive sector poses.[4]

One image processing solution that leverages a number (the license plate) to find the automobile is called automated license plate recognition (ALPR). The objective is to design a system that uses license plates and vehicle numbers to identify approved cars effectively. The system is put at the entry to secure the safety of a restricted location, such as a military zone or the neighborhood of a key government office (such as the Supreme Court or Parliament). The technology can recognize and photograph cars. The region holding the vehicle's license plate is located in a photograph that has been split. Optic character recognition is used for character recognition. After that, it is compared to records in a database to gather facts like the car's owner, registration location, address, etc. System performance is tested using real photographs. Experiment results show car number plate identification and recognition on real photos. [5]

This article recommends automating roadside surveillance camera monitoring of fast-moving automobiles. Real-time background CCTV video collection is time-consuming. YOLO, a sophisticated deep learning model, detects objects to solve this. The intended task has four main parts. First, take stills from the video and identify each car. Next, identify automobiles by license plates. Reading and recognizing license plate characters is the final stage. ImageAI simplifies training for the proposed deep learning model. The model is tested using photos of the Tamil Nadu license plate. Automobile identification, number plate localization, and character recognition are 97%, 98%, and 90% accurate. [6]

This study presents a durable and efficient ALPR system. The recommended method employs a 1-stage CNN and 3 YOLO phases. YOLO and CNN end with

segmentation and character recognition. Our dataset for the YOLO phases includes 604 photos of automobiles in their natural contexts from different angles and lighting. CNN was trained on a 42237-character computer dataset. For the final system, 50 randomly selected test pictures were used. Despite an 82% ultimate accuracy with substantial error tolerance on 50 test images, all four validation phases exceed 90%. Instead of Image Processing, deep learning may identify deformed license plates. YOLO stages 1 and 2 were 100% accurate in validation and test sets. [7]

Nowadays, it is hard to examine data from the many cars on the road. Thus, automating car data collection is essential. License plates help identify cars. Automatic license plate recognition is suggested in this article. The suggested method improved Faster R-CNN with an adaptive attention network to retrieve license plate digits and letters. The features extraction network is improved by adding a top deconvolution layer to detect the tiny target license plate. The proposed approach was taught and tested in Egypt, KSA, and UAE, utilizing license plates with Arabic and Indian digits and Latin alphabets. [8]

Even with the best algorithms, ANPR systems may need extra hardware to improve accuracy. Processing and memory challenges, ambient conditions, non-standardized formats, complicated sceneries, camera quality, mount location, distortion tolerance, motion blur, contrast, reflections, software tools, and hardware-based limits might affect performance. ANPR's intricacy, unpredictability, and difficulty make it intriguing to examine. ITS is expanding and affecting numerous areas because of the IoT. Adding RFID, GPS, Android, and other technologies to ANPR might improve its usage. Deep-learning techniques are often employed to improve CV detection rates. This study attempts to advance CV-based ITS (ANPR) knowledge by reviewing the literature, conducting in-depth analyses, evaluating extraction, segmentation, and recognition methods, and making recommendations for future research. [9]

License plate recognition is a hot topic in deep learning research. This project's best deep learning model was chosen based on its ability to meet system operating criteria, including speed, accuracy, and precision. Thus, the YOLO (You Only Look Once) approach was employed to process several photographs efficiently and produce results with one glance. A neural network with a single field of vision can distinguish many items in a picture using YOLO. This investigation locates license plates with YOLOv3. To simplify character identification, image warping, and slicing straighten the image. After filtering PyTesseract results with bad predictions with the RegEx function, They read the characters from the picture using PyTesseract. From 5 movies from Universiti Malaysia Pahang's main entry security gate CCTV system, this method detected vehicle license plates with 100% accuracy. [10]

The control and surveillance systems depend on vehicle recognition. The blend of letters and numbers on car license plates makes them instantly recognizable. People must work hard to recognize all parked or passing car number plates manually. This research proposes a training-based license plate detection method. Most ANPR system research has been done in constrained settings with fixed illumination, restricted vehicle speeds, interior spaces, specified driveways, and static backdrops. We focus on creating a reliable number plate identification model in different lighting situations and angles. Recognition model utilizing YOLO V3 on manually collected car license plates. The algorithm was tested with 640 pictures of various hues and lighting. [11]

This study uses deep learning and data from Iraq and Malaysia to distinguish Arabic and Latin license plates. The research system locates, separates, and identifies license plates. Additionally, Iraqi and Malaysian plates were used to compare these techniques. All proposed solutions were applied to 681 Malaysian and 404 Iraqi photos. Weather conditions such as fog, contrasts, dirt, hues, and distortion were tested. The approach has an average recognition rate of 85.56% on the Iraqi dataset and 88.86% on the Malaysian dataset. The deep-learning-based technology outperforms earlier techniques by reliably recognizing plate numbers despite images with varied degrees of deterioration. [12]

A dual-deep-learning-based automated license plate identification method for Indian drivers is proposed. The

recommended method revives databases of extremely inconsistent Indian typefaces, including number plates, and efficiently builds a bespoke dataset of Indian font variations, outperforming previous methods. The CNN model (Tensorflow) was trained for word recognition using the dataset and YOLO V3 for ROI detection. Our model was validated using RTO database data; the OCR model had 91.5% accuracy, and the YOLO model was 96%. Our system needs to be improved to recognize RTO drivers from the video stream and extract their data using the RTO API. [13]

This article describes a method for automatically recognizing helmetless motorcyclists in surveillance film and collecting license plates. Transfer learning and CNNs can identify bikers without helmets. The technology can recognize and record motorbike license plates, which the Transport Office may use to obtain information on motorcyclists from its database of registered cars! Additionally, we learned how to generate challans and locate stolen automobiles. This article describes a method for automatically recognizing helmetless motorcyclists in surveillance film and collecting license plates. Transfer learning and convolutional Neural Networks (CNN) can accurately recognize bikers without helmets; spotting them and bogus news against them is crucial! Worried motorcyclists may suffer sanctions, but not always! However, more must be done to identify and punish motorcyclists. The system can also record their motorcycle license plates. The Transport Office can use license plates from registered cars to acquire cyclist information. Worried motorcyclists may be punished. Additionally, we learned how to generate challans and locate stolen automobiles. [14]

Numerous academics are studying number plate recognition. Number plate recognition identifies automobiles. In this article, Deep Learning convolutional neural networks convert handwritten character photos into editable text. Convolutional neural networks detect automobile license plates, and picture denoising removes noise. Warped or skewed images require image segmentation. Regular Expressions verify string format. The recovered number can be used in electronic payment systems, including challans, parking charges, and toll payments.[15]

Specialized systems for detection and license plate recognition can identify intrinsic from non-intrinsic vehicle detection approaches. However, using a software-based method reduces system dependence instead of an inherent one. The survey might provide methodologies, benefits, disadvantages, and efficacy. The survey above may provide valuable insight into the procedures used. Through evolving methodologies and an understanding of distinct environments, scholars have used numerous strategies to outperform others. As processing power increases, machine learning will be beneficial for more detection and classification applications. Studies proposed improving vehicle detection methods and capabilities. [16]

This paper proposed an ANPR algorithm. The plate localization approach considers plate shape and size while determining outlines. The CS algorithm uses contour area because plate size is normalized. The third number recognition approach employs a Jetson TX2 board-trained CNN. Precision reaches 0.9584. [17]

This research shows that deep learning algorithms are more effective in India's ANPR procedure when anomalies are present. The writers of the whole end-to-end ANPR detected many lines of LP, uneven padding, unusual plates, fonts, and font sizes. This showed a complete ANPR process. We suggested an LPD model and CR network method that fit the Indian situation. The LPD model learned at 92% and had 96.23% accuracy with a detection threshold of 0.5; its precision of 98% caused its death. Using tiny bus and vehicle license plates and losing less than 10%. When multiline panels were considered, the suggested network predicted 93.7% of characters with a confidence level above 90% and averaged 94.9%. ANPR can identify vehicle owners, models, traffic voltage and control, and location. A multilingual ANPR adaptation of this technique allows automated character language detection using training data. [18]

Technology is rapidly changing; therefore, safe living and travel are needed. Road traffic has increased during the past decade. Tracking individual automobiles becomes increasingly difficult as the auto industry grows exponentially. Real-time background CCTV video

collection is time-consuming. YOLO, a sophisticated deep learning model, detects objects to solve this. The intended task has four main parts. First, take stills from the video and identify each car. Next, identify automobiles by license plates. Finally, the characters from the detected number plates are read and recognized. ImageAI simplifies training for the proposed deep learning model. The model is tested using photos of the Tamil Nadu license plate. Vehicle detection was 97% accurate, license plate localization 98%, and character recognition 90%. [19]

This article describes ALPR vehicle administration processes. An automobile video is submitted, and the license plate number is texted. The template matching technique identified the license plate and suggested similar plates based on its aspect ratio, area, height, width, distance between letters, angle between them, and change in area. The Convolutional Neural Network Outperformed K Nearest Neighbours. Finally, an 8-layer convolutional neural network completed optical character recognition. The exam set averages 85% correctness. We present an algorithm that can detect license plates and extract text faster and more reliably under specific conditions. Low-quality or fuzzy pictures cause low classifier performance because '0', 'O', and '1' may be mistaken with 'I.' To improve this, train the CNN classifier on more character images of various types. Use more robust methods that can generalize to new circumstances or adjust the parameters to match the license plate structure of that nation or location to improve template-matching for license identification. The CNN classifier will process fewer characters by lowering the number of plates. Parallelization can boost ALPR system processing speeds when used in different development phases. [20]

In developing countries, motorbikes are the main mode of transportation; therefore, few vehicles are seen. Recent years have seen more motorbike accidents. Motorcyclists who cause traffic accidents do not always wear fluorescent helmets because they do not think they are protective. Traffic officers may seize and prosecute unhelmeted motorcyclists on the road or at junctions. CCTV video supports this strategy. Human initiative and effort are needed to achieve it. Classification decides whether a vehicle is a motorcycle. A motorcyclist's head may be full or non-full, depending on its design. Next, the identification algorithm retrieves missing characters using outstanding photo analysis. The motorbike's character count is then evaluated using optical character recognition software. This Object Detection Algorithm can locate faces in images and videos. CNNs are suitable for image recognition and classification because of their accuracy. In a hierarchical architecture, the CNN builds a funnel-like network with a fully connected layer that processes output by linking all neurons. [21]

Automatic license plate recognition uses a number (the license plate) to find the automobile. The aim is to use a license plate and vehicle number-based system to identify approved cars efficiently. The device is at the entrance to protect a military zone or a key government facility like the Supreme Court or Parliament. The technology can recognize and photograph cars. The license plate is in a divided photo. Optical character recognition is utilized. After that, it is compared to a database to find the car's owner, registration location, address, etc. System performance is tested using real photographs. The research shows that the technology detects license plates in real photos.[22]

III. Proposed System

Fig. 1 shows the block diagram of the proposed system. The block diagram illustrates the successive vehicle number plate identification and recognition phases. Each block symbolizes a unique phase in the process, beginning with entering a vehicle picture and ending with identifying the alphanumeric letters on the number plate.

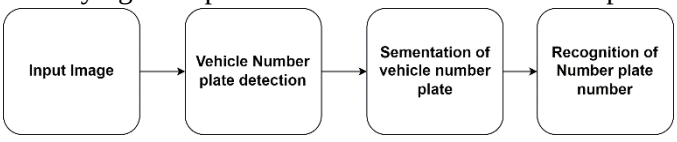


Fig.1 Block diagram of the ANPR system

A. Input Vehicle image

This block displays the first stage of the process, where an input image that contains a vehicle is acquired. The form of a raw input data image with a vehicle may either be obtained from a camera or taken out of the image database.

B. Vehicle number plate detection

Detection of candidate regions in the input image through a Python-based computer vision library called OpenCV. It has many subprocesses: preprocessing, contour detection, contour approximation, filtering, and rendering. Preprocessing techniques can resize, convert to grayscale, and perform noise reduction. These would improve the quality and allow ease in the processing steps involved after this. After that, the contour detection algorithm is applied, which detects the outlines or contours of objects in an image, thereby considering it a candidate for the number plate regions if the contours are rectangular-shaped. Such contours are approximated by the function approxPolyDP so that the shape can be simplified, and contours close to a rectangle are found. Therefore, in the resulting image, only those filtered contours bound to give a number plate are visualized to verify and debug the detected contours.

C. Segmentation of number plate

Once all the number plate candidates have been successfully detected, the regions of the number plates shall be segmented by isolating the regions from the rest of the image. The segmentation step follows cropping out of the rectangular regions defined by the detected contours to extract candidate number plate regions. Optionally, for further improving the quality of all recognition steps, the cropped number plate regions may be subjected to preprocessing: spatial resolution resizing, normalization, and contrast enhancement. The system segments the regions of the number plate, so its processing is focused only on the regions of interest to allow easier and more accurate recognition of the characters on the number plate.

D. Recognition of number plate numbers

In the final stage, the segmented region of the number plates is passed to Optical Character Recognition (OCR) to take out alphanumeric characters that occur on the number plates. This OCR stage includes preprocessing, character segmentation, and character recognition. Preprocessing techniques of binarization, noise reduction, and enhancement are applied to recognize the characters within the cropped number plate images properly. After that, the preprocessed image was segmented using connected component analysis or contour-based segmentation into individual characters. The segmented characters are inputs to an OCR engine built using the EasyOCR library, which employs deep learning models to recognize and extract segmented alphanumeric characters from the images. The final identified characters are outputted, and the recognition of the vehicle number plate is recognized as a result of number plate recognition, which forms a comprehensive system of automated vehicle number plate identification and recognition.

IV. Implementation

This section presents the implementation of the proposed system.

A. *Software and Hardware*

A collection of hardware and software components make up the ANPR system. Python is at the core of the software stack, which also contains OpenCV for image processing jobs like license plate identification, EasyOCR for OCR, and PyQt5 for GUI development. In terms of hardware, the system necessitates a computer to execute the Automatic Number Plate Recognition (ANPR) software, a camera to record moving pictures or videos of cars, and, if desired, a Graphics Processing Unit (GPU) to speed up image processing.

B. *Image Processing and OCR*

To ensure precise license plate identification, the ANPR system uses several image processing algorithms to improve the input photos. Some examples of these methods include converting images to grayscale for easier representation, using bilateral filtering to cut down on noise without losing any of the edges, and using edge detection algorithms to find license plate-containing areas of interest. The technology can correctly read the alphanumeric characters on the license plate after detecting the license plate area. EasyOCR is used for character extraction and recognition.

C. *Database Structure*

The system depends on an organized database to store and retrieve car information from the recognized license plates. Databases usually include tables that store information like license plate numbers, owners of those numbers, when a vehicle was seen, and any other

important metadata to the application. The database enables car monitoring and administration functions by methodically structuring data, allowing effective searching and retrieving of vehicle information.

D. *GUI Design*

An intuitive means of interfacing with the ANPR system is provided by the GUI, which is based on PyQt5. Among the many features and components included in the GUI are controls for initiating and terminating the automatic number plate recognition (ANPR) process, the ability to view live or recorded camera feeds, real-time presentation of recognized license plate numbers and related vehicle details, and the execution of administrative tasks like database management and system configuration. Due to the GUI's easy design, users may easily explore the various functions and get the necessary information.

We combined software and hardware elements to create the Vehicle Number Plate Identification and Recognition System (VNPIRS). Utilizing image processing and optical character recognition (OCR) techniques ensured precise license plate identification. We established a database for efficient storage and retrieval of vehicle data. The user-friendly GUI was developed using PyQt5 to interact with the ANPR system seamlessly. The primary objectives of implementing these strategies for detecting and recognizing vehicle number plates from images and videos include enhancing traffic control, security, and law enforcement.

E. Implementation of this project

- **Code Walkthrough:**

Python is crucial in constructing the ANPR system, utilizing libraries like OpenCV, PyQt5, and EasyOCR for tasks such as image processing, OCR, and GUI development. Various classes and functions are integrated into the code, each assigned distinct responsibilities for different aspects of the ANPR process.

- **VideoWidget Class:**

The VideoWidget class mostly displays live and recorded camera feeds. It processes camera frames using image processing algorithms and shows the findings on the GUI using OpenCV. VideoWidget handles the camera and video playback controls.

- **MainWindow Class:**

The MainWindow class represents the ANPR system's main GUI. Button, text box, and video display zones are included to simplify the system. The MainWindow class takes user input, launches ANPR algorithms, and refreshes the graphical user interface with license plate numbers and vehicle data when a button is pressed.

- **Detect and Extract Number Functions:**

ANPR's detect_number and extract_number routines are vital. The detect_number method should flag license plates in photos. Images are processed using edge detection and contour analysis to discover license plate regions. When a license plate is detected, the extract_number method retrieves it from the photo.

- **EasyOCR Integration:**

Integrating the EasyOCR library into the ANPR system optically recognizes the recovered number plate region. EasyOCR successfully identifies alphanumeric characters from photographs using deep learning. Besides timestamps and location data, the database holds recognized characters and other vehicle data.

Python classes and functions govern video presentation, number plate detection, character extraction, and database interaction for the automated number plate recognition system. The strong and effective ANPR system employs several libraries and methodologies to automate vehicle identification and number plate recognition from photographs and videos.

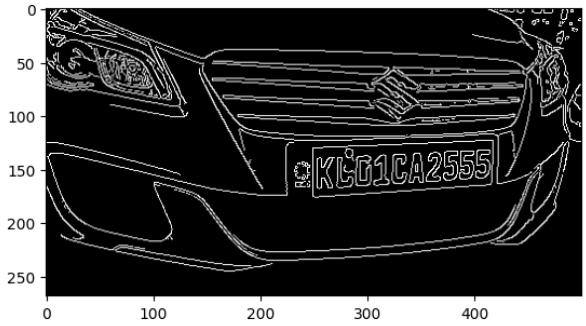
F. *Integration and Real-time Recognition*

Construct a unified system combining the YOLO detection and optical character recognition components. Efficiently identify and recognize car license plates in live video feeds using real-time processing.

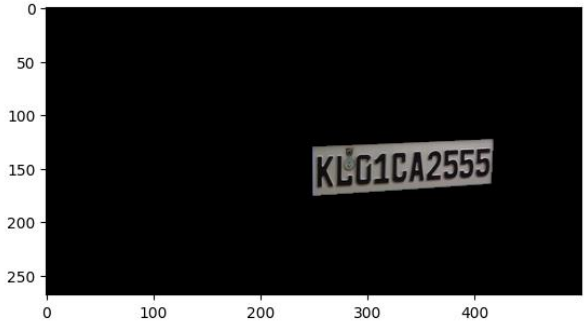
V. Results

The proposed system is implemented in a Python environment. The step-by-step results of the vehicle number plate detection and recognition are presented in this section.

(a)



(b)



(c)

(d)

(e)

Fig.2 Results of the proposed automatic number plate recognition system (a) Input vehicle image (b) Edge detection output (c) Segmentation of the number plate (d) number plate detection output (e) Vehicle number recognition output

The result of the proposed automatic number plate recognition system is shown in Fig. 2. All the processes were sequential and initiated from the input vehicle image, which is finally analyzed after processing to highlight the contours. It then segments the number plate region and returns the number plate detection, where the candidate regions quite similar to the number plate are highlighted. Finally, OCR is used to extract and interpret the alphanumeric characters from the detected region of the number plate. The input images of the vehicle number plate give clear detection and accurate recognition of the Alphanumeric characters in the images, which are well-identified by the system. These results prove the robustness and efficiency of the proposed system for real-world situations, thus opening the potential for using it in applications, namely law enforcement, traffic management, and security surveillance.

VI.CONCLUSION

The present paper highlighted the developed and evaluated automatic number plate recognition (ANPR) system, which comes with quite promising results and contributes significantly to furtherance in computer vision and deep learning-based image processing. The system has yielded results for the correct detection and recognition of number plates of vehicles from input images by applying advanced methods like contour detection, segmentation, and optical character recognition (OCR). The proposed methodology, developed with Python, OpenCV, and EasyOCR, proved robust and efficient for all diverse conditions in real-time scenarios with different lighting variations, vehicle orientation, and environmental factors. The sequential process for the proposed methodology is given in the flowchart presented in Figure 1. The approach adopted by the system is systematic; it starts from the preprocessing of the input images, and finally, the system applies the highest level of accuracy and reliability in number plates' identification and recognition tasks by using state-of-the-art algorithms deployed in deep learning models. Indeed, these findings confirm the potential of deep learning techniques to

heighten the abilities of real-time automated systems for number plate recognition, with cascading implications across various practical applications ranging from law enforcement traffic management to security surveillance.

At the same time, the authors underlined the limitations of the proposed system that needed further optimization and validation on larger datasets and in real deployment. This suggests a few lines of further work in this field: enhancing the robustness and scalability of the system, experimenting with alternative deep learning architectures, and addressing such problems as occlusion, variation of font style, and the license plate design in different regions. In sum, the studies have demonstrated that automatic number plate recognition systems contribute to or contribute towards security, efficiency, and safety improvement in the transportation and surveillance domains, respectively. Further scope of work would mean refinements of the ANPR system for robust work in challenging conditions through advanced deep learning technique integration and better scalability for the deployed real world and delving into some in-depth complementary technologies that offer richer functionalities and could support applications in smart cities and transportation systems.

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