Automatic License Plate Detection using YOLOv9

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***Abstract*— With the booming economy and better-than-ever road infrastructure, a growth in the count of motor vehicles moving on the road has been noticed. This increase in the number of vehicles may lead to various problems happening such as increased frequency of accidents, more violations in motor violations, and sometimes may lead to crimes as well. Hence, vehicle monitoring becomes a huge factor in overcoming these situations since manual monitoring of vehicles will become obsolete due to the large volume of vehicles as well as the high speed at which they travel. In this study, a project has been evolved for license plate identification using a Convolutional Neural Network (CNN) which happens to be a technique used for the deep analysis of algorithms. The primary objective of this report is to provide a comprehensive exploration of ALPD techniques, with a particular emphasis on leveraging the YOLOv9 architecture for robust and efficient detection. An automatic license plate detection system based on YOLOv9 has been presented as a means of advancing the state-of-the-art in automatic license plate detection and contributing to the development of smarter, safer, and more sustainable urban environments.**

Keywords—License plate detection, Image texture analysis, YOLO, Bounding Box Method, Computer Vision

I. Introduction

A sudden boom in the amount of motor vehicles on road due to economic growth as well as road infrastructure growth has led to a huge demand for automatic vehicle monitoring systems as manual monitoring becomes useless since vehicles are fast moving on the road and the sheer volume of them is very high as well. Manual monitoring also has the downside of wasting human resources in terms of time and energy which could have been utilized in another appropriate places. The chances of error happening also increase quite a bit in this way. Hence the need for a proper and fast working solution grows. There are already many solutions out there for license plate detection using many different algorithms on machine learning. But in present scenarios, these program codes tend to fail due to the difficulty of real-world alternatives.[11] As a result, there lies a necessity for continuous development and evolution of technology that can help in tracking of vehicles as well as accurate detection of license plates. Automatic License Plate Detection System (ALPD) happens to be an important component in traffic systemization and control. By nature, information related to traffic is difficult to store, process and manage. The Automatic License Plate Detection framework is capable of detecting vehicle license plates, collecting information on it, storing the data in a structured format and use the data for analysis in various other implementations such as traffic management, priority lanes for public vehicles, etc. ALPD is the basic level of automation in the travel or transportation field. Effective approaches involve first classifying vehicles within the frame and subsequently narrowing down the search to the bounding boxes enclosing the vehicles.

II. Literature Survey

Considerable measures have been undertaken in recent years in the field based on Automatic License Plate Detection with numerous studies in multiple varieties of practices and procedures used. [6] There are many used and suggested techniques in the proposed license plate detection literature. Various techniques such as discerning the region of license plates derived from recorded visuals, intensifying computerized images, separating the characters, focusing on character recognition are suggested in this literature. [4]

- Falguni Verma et al carried out a study centering the incorporation of YOLOv5 into Automatic License Plate Detection (ALPD) using easyOCR. Specific detailed information about their research was not available but the highlights of their study in the implementation of YOLOv5 in license plate detection as well as exhibiting its capability in this sector. [7]

- Kiran Wadare et al conducted a research study focusing on utilizing YOLOv8 along with easyOCR for Automatic License Plate Recognition (ALPR). Their work emphasizes the application of YOLOv8 along with easyOCR for the purpose of detection and character recognition respectively. [8]

- Shashidhar Rudregowda et al conducted a research study on ALPR using YOLOv3 and OCR using CNN. Their work highlights the application of YOLOv3 for region of interest detection and the CNN based OCR for character recognition even in blurry images.[9]

- Reda Albatat et al conducted a research study on ALPR using a vehicle that was a YOLO-based integration with license plate detection and vehicle classification. The most notable aspects of their work were the application of v2 detector for stage 1 and in stage 2, v4 detector in darknet framework along with a vehicle type categorizer that uses a ResNet50.[10] Building upon these prevailing studies, the paper aims to pioneer in the integration of YOLOv9 in ALPD systems. The aim is to explore the capabilities of systems in the detection of license plates and the accreditation of high precision and efficacy. Using the distinctive and one-of-a-kind

  features of YOLOv9 and its enhanced detection speed and accuracy over its predecessor, this research targets to push forward and develop the state of the ANPD network by making them faster and more accurate while also contributing to the field of customary computer vision and pattern identification.[5]

Sno.	Title	Summary	Methodology
1	Automatic License Plate Recognition with Few Constraints on Working Environment	This paper presents an ALPR technique to operate under minimal constraints. It consists of two main modules: license plate locating and license number identification. Fuzzy disciplines and neural subjects are employed for each module, respectively. Experiments demonstrate high success rates in locating and identifying license plates.	The methodology involves fuzzy disciplines for license plate extraction and neural networks for character recognition. Key techniques include color edge detection, fuzzification, self-organizing character recognition, and two-stage fuzzy aggregation.
2	Fast and Real-Time License Plate Recognition Method for Plates with Tilt and Poor Picture Quality	This paper introduces a fast and real-time method for License Plate Recognition (LPR), particularly designed for plates with tilt and poor picture quality. It utilizes adaptive thresholding, edge detection, morphology operations, and K Nearest Neighbour (KNN) classifier for character recognition. Experimental results show high accuracy rates, even on challenging images.	The methodology includes adaptive thresholding, edge detection, mathematical morphology, and KNN classifier. Testing is performed on datasets with varying backgrounds and angles of view.
3	Advanced Automatic Number Plate Recognition System with Deblurring Capability	This paper presents an advanced Automatic Number Plate Recognition (ANPR) system with deblurring capability. It employs YOLO V3 for Region of Interest (ROI) detection and Convolutional Neural Network (CNN) for optical character recognition (OCR). A novel aspect is the ability to deblur images before applying machine learning models.	The methodology involves YOLO V3 for ROI detection, CNN for OCR, and image deblurring. Additionally, a dataset is created for model training, and pre-processing steps are applied to enhance the detected ROI. Cross-checking with the RTO database ensures accurate recognition.

III. Proposed Methodology

The suggested framework is made up of a virtual recording device for input of videos or images and different other components for the detection of license plate. The steps are in the following manner:

- Image Capture and Information: Initially, a camera records a photograph or footage (recorded clip or visual livestream) accompanied by single or multiple license plates in the frame and passes it to the model. Since many cameras have infrared lighting to enable the cameras to obtain pictures or videos at night or in low lighting, this allows ALPD the opportunity to operate round the clock.

- Classification: Classification is nothing more than classifying the objects into categories where they belong such as car, bus, bicycle, person, tree, etc. In this step, the model classifies the various objects present in the frame and draws a bounding box around them.

- Extraction: Different methods differ in the materialistic requirements including factors such as accuracy, speed, real time complexity, etc. One of the best ways for extraction is to first classify the vehicles, then to classifying the license plate within the bounding box of the car.[2] This is generally done by searching for distinct settings and then for licenses in the bounding box of those backgrounds.

- Plate Localization: Localization of the Vehicle Plate connects the plate to the overall view. The license plate is then identified and verified, and the aforementioned result happens to be a frame comprising the license plate.

In the proposed system, the output for an image is another image with bounding box for license plate marked and the confidence of the algorithm on that bounding box. [1]

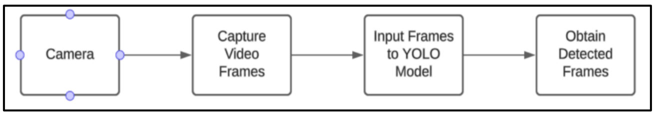

Fig. 1. Image/License Plate Acquisition Process

Currently, the system is composed of license plate area detection and authentication only due to presence of bugs in YOLOv9 due to recent public release.[3] Future updates using some OCR algorithm/techniques can be added to convert the system into a complete ALPR (Automatic License Plate Recognition) system.

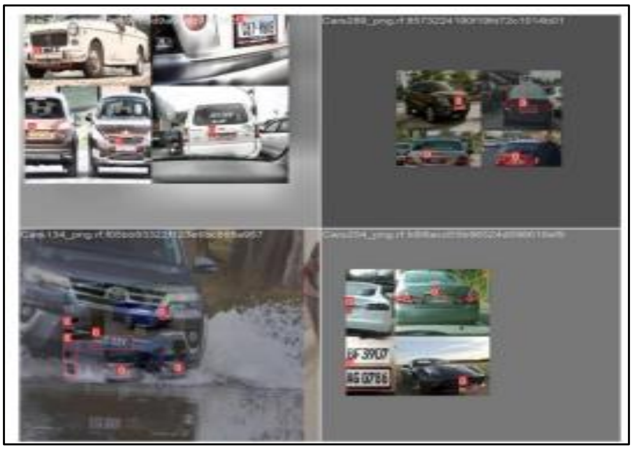

Fig. 2. Training Batch 1

Fig. 3. Validation Batch 1

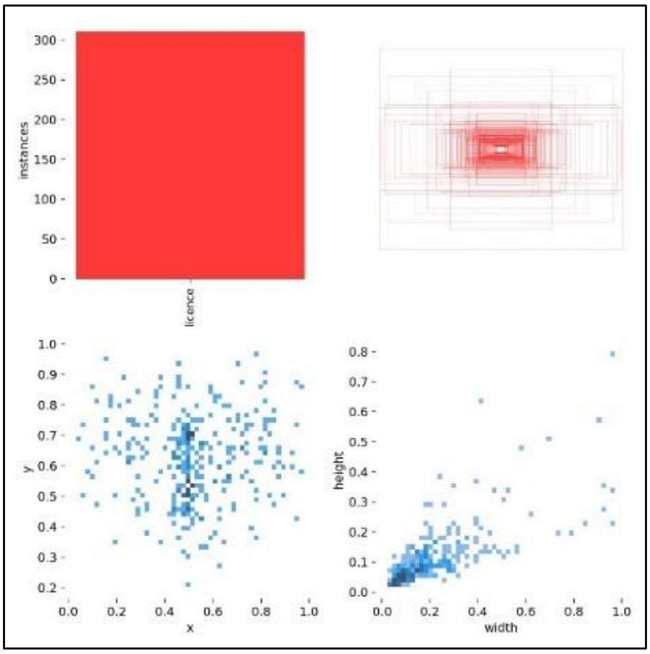

Fig. 4. Labels and Instances

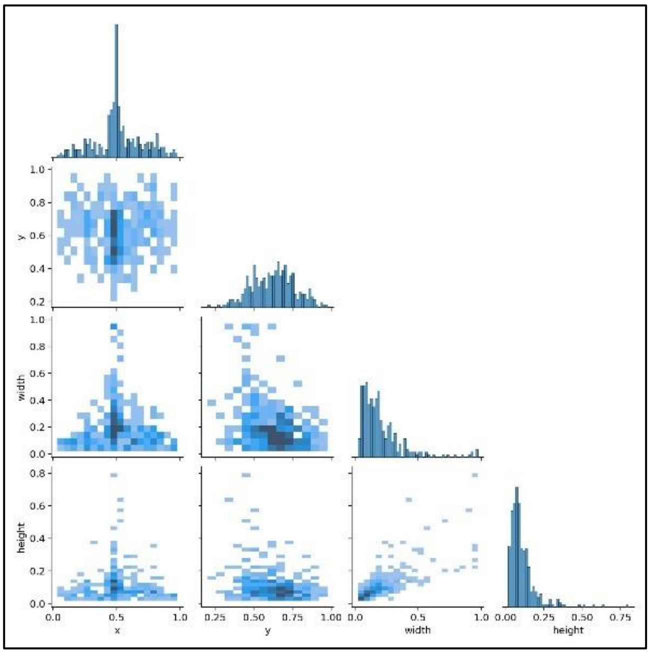

Fig. 5. Labels Correlogram

IV. Training and Simulation

After accumulating the trained data from the dataset, these are the simulations from the given algorithm. Figure 2 exhibits the progress of the algorithm during training and Figure 3 shows it's on Fig. 1, even at the beginning of a sentence.

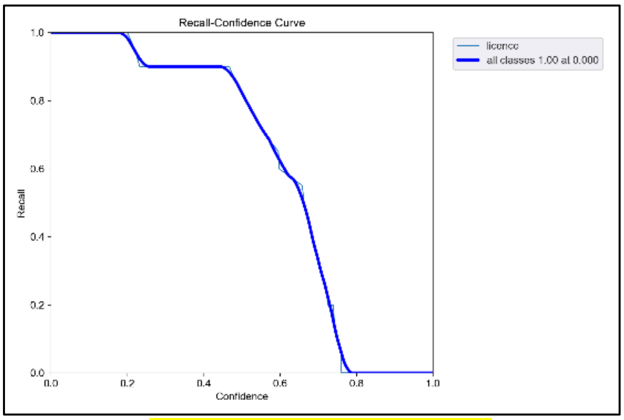

Fig. 6. Recall-Confidence Curve

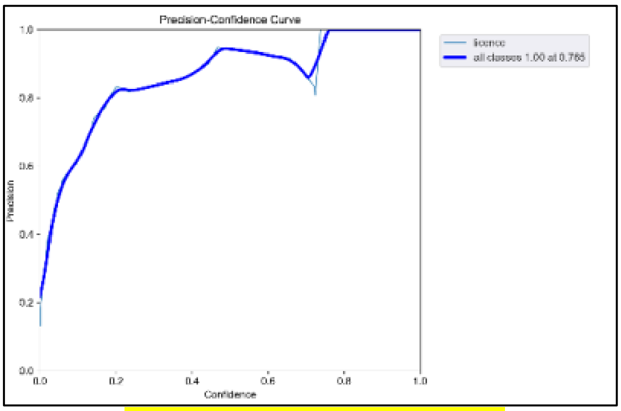

Fig. 7. Precision- Confidence Curve

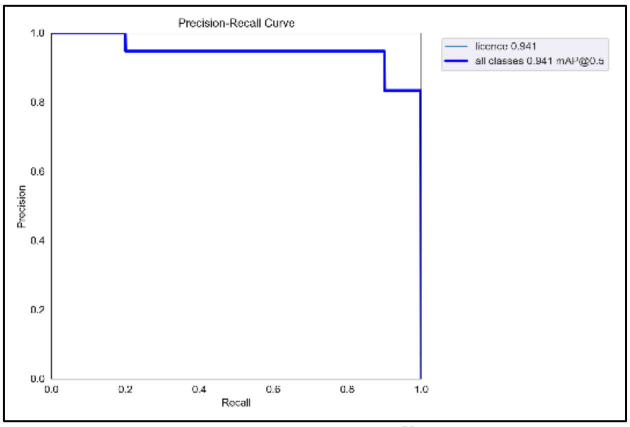

Fig. 8. Precision-Recall Curve

V. RESULTS

Figure 9 below shows the mean precision and box loss.

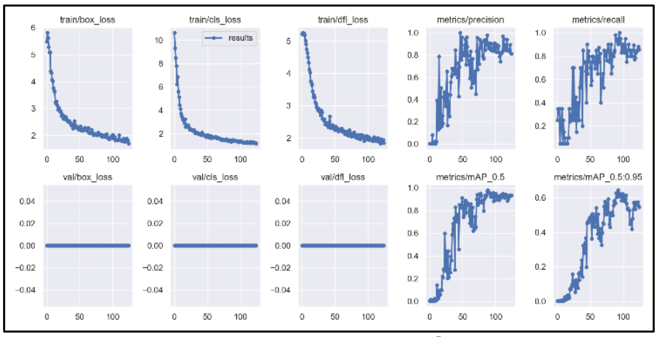

Fig. 9. Mean Precision and Box Loss

Figure 10 shows the f1 curve and hence helps us analyze the model and check how much better the performance is.

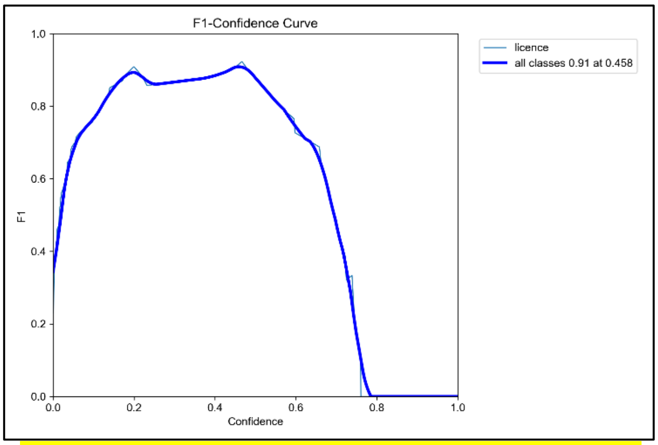

Fig. 10. F1 Curve [Harmonic mean of precision and recall]

Figure 11 shows the True Positive, True Negative, False Positive and False Negative that are displayed by the confusion matrix. We obtain these results after training the model. This prototype has an estimated accuracy of 90%.

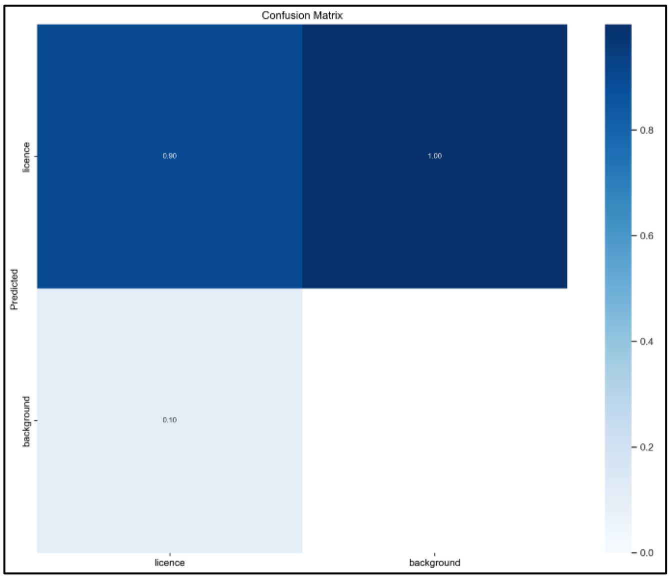

Fig. 11. Confusion Matrix

Below are the outputs of our model which used YOLOv9 in identifying and obtaining the license plates concerning multiple motor vehicles in their respective recordings.[21] As can be seen in Figure 14, although with low confidence, the system detects the logo of a car as the license plate. With more data and training, this can be rectified.[17] Figures 12 through 14 are photographs obtained from the model, which detects plates with an accuracy of 93%.

Fig. 12. Show outcome 1 with high level of accuracy

Fig. 13. Outcome 2 detecting moving vehicles

Fig. 14. Detection of logo and license plate

VI. FUTURE SCOPE

Future Directions: Anticipating future advancements and potential expansions of the automatic license plate detection system, the following directions merit consideration for future research and development:

- Integration of Machine Learning for Adaptive Enhancement: Exploring the consolidation of machine learning techniques, such as reinforcement learning or adversarial training, can enable the system to adapt and optimize its performance based on real-world response. This adaptive enhancement strategy holds promise regarding continuously improving detection accuracy and robustness across diverse operating conditions.

- Deployment of Edge Computing Solutions Investigating the feasibility of deploying edge computing solutions to facilitate real-time processing and analysis of video streams directly at the edge devices represents a compelling avenue for future development. Edge computing architectures can alleviate latency concerns and enhance the system's responsiveness, particularly in resource constrained environments. [15]

- Exploration of Multimodal Fusion Techniques Exploring multimodal fusion techniques that integrate information from various sensor modalities, such as visual, thermal, and LiDAR data, can enrich the system's perception capabilities and resilience to challenging environmental conditions.[16] Leveraging complementary sensor modalities can enhance detection performance under adverse weather conditions, low-light environments, and other challenging scenarios.

- Investigation of Privacy-Preserving Mechanisms Considering the increasing concerns regarding privacy and data security, exploring data-protective mechanisms, such as collaborative learning or differential privacy, can alleviate risks related to the collection along with processing of sensitive vehicle information. [19] Implementing robust privacy safeguards can foster broader acceptance and adoption of the license plate detection system while upholding individual privacy rights.

- Collaboration with Industry and Government Stakeholders Engaging in collaborative partnerships with industry stakeholders, government agencies, and law enforcement authorities can foster the incorporation of the license plate detection system into broader [12] smart city projects and public safety frameworks. Collaboration facilitates access to real world deployment scenarios, domain expertise, and regulatory insights, thereby enhancing the system's relevance and impact.[14]

VII. CONCLUSION

In this specific research document, an Automatic License Plate Detection (ALPD) network utilizing YOLOv9 is demonstrated. Image processing methods are used to discern motor automobiles, then for which the license plates are then detected. The given framework operates sufficiently in different conditions and is able to detect different types of license plates. [13]The system even works decently for some low-resolution inputs. There is also huge room for improvement as well as for adding more features. One of the main improvements could be the addition of some OCR system to the system to make a full-fledged recognition system instead of just a detection system. Some other suggestions for improvement are

- Speed and accuracy of detection can be increased by using advanced cameras for input of HD video feed.
- Another system can be added to differentiate public support vehicles such as ambulances, buses, fire trucks, police cars, etc. from other motor vehicles.
- Statistics such as speed limits, current speed, text on vehicles, etc. can also be taken into account to further improve the algorithm. [20]
- The OCR technique is susceptible to distortions, misalignments and diverse dimensions of the characters.

Therefore, training a custom model with varied types of templates and with multiple RTO requirements can help additionally in character recognition.[18]

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