

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. [11] 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. Effective approaches involve first classifying vehicles within the frame and subsequently narrowing down the search to the bounding boxes enclosing the vehicles. 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. 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

using 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 travel or transportation field.

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. 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. • 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.

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. 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.



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. 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

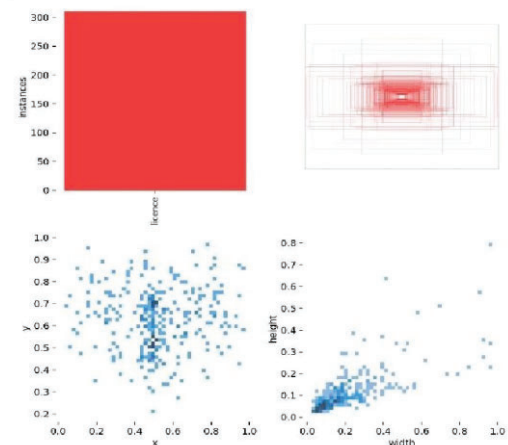


Fig. 4. Shows the Labels and instances

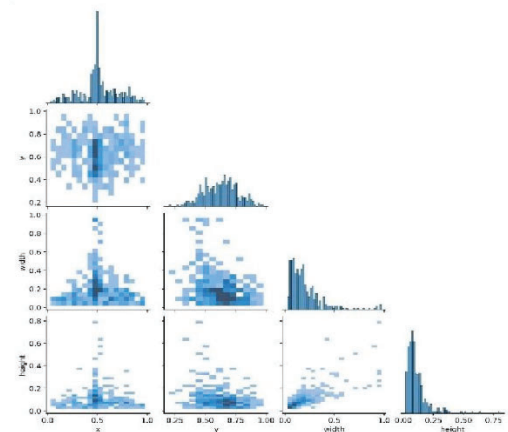


Fig. 5. Labels Corrologram

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.

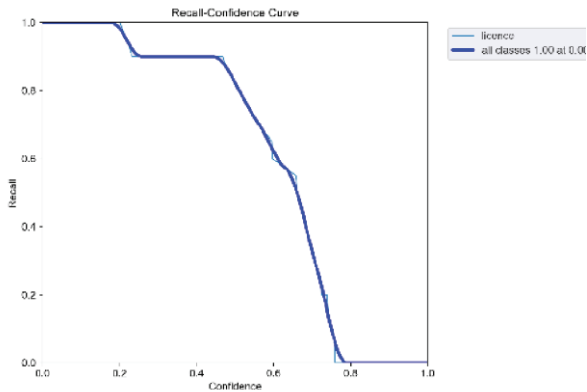


Fig. 6. Recall Curve.

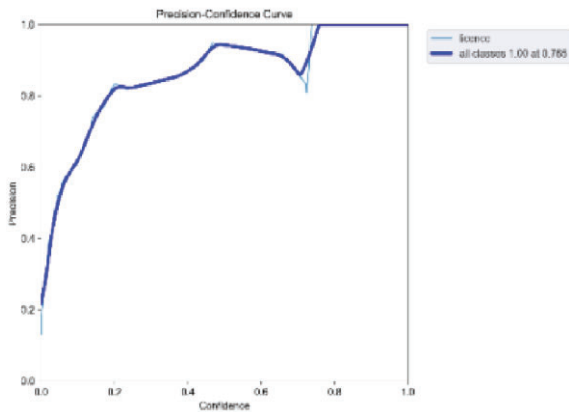


Fig. 7. Precision Curve

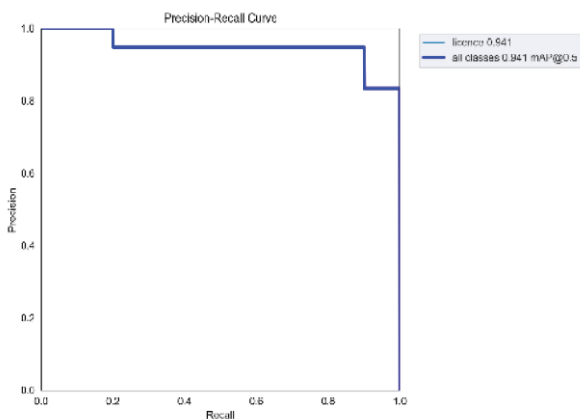


Fig. 8. Precision-Recall Curve

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. 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. Figures 12 through 14 are photographs obtained from the model, which detects plates with an accuracy of 93%.

V. RESULTS

Figure 9 below shows the mean precision and box loss.

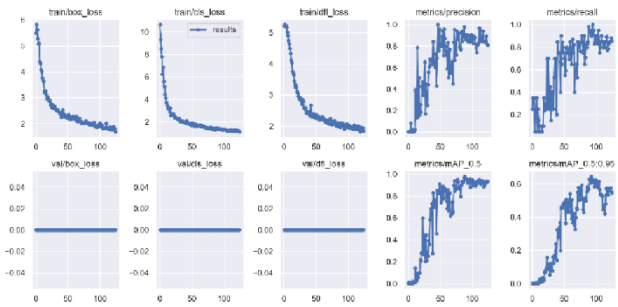


Fig. 9. Mean Precision and Box Loss

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

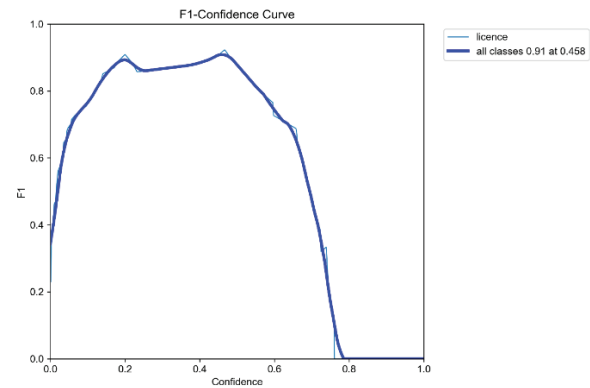


Fig. 10. F1 Curve

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 a estimated accuracy of 90%.

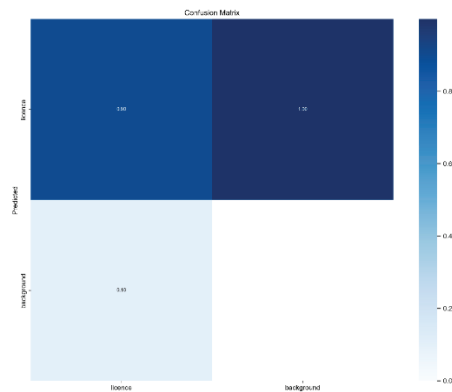


Fig. 11. Confusion Matrix

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. 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. Figures 12 through 14 are photographs obtained from the model, which detects plates with an accuracy of 93%.



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



Fig. 13. Show the outcome 2



Fig. 14. Detection of logo and license plate

VI. FUTURE SCOPE

A. 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 resourceconstrained environments. [15-17]
- **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. 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. 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**

B. 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 [12-14] smart city projects and public safety frameworks. Collaboration facilitates access to realworld deployment scenarios, domain expertise, and regulatory insights, thereby enhancing the system's relevance and impact.

VII. SUMMARY

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. The system even works decently for some lowresolution 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.
- 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.

REFERENCES

- [1] Shyang-Lih Chang, Li-Shien Chen, Yun-Chung Chung and SeiWan Chen, "Automatic license plate recognition," in IEEE Transactions on Intelligent Transportation Systems, vol. 5, no. 1, pp. 42-53, March 2004, doi: 10.1109/TITS.2004.825086.
- [2] S. Du, M. Ibrahim, M. Shehata and W. Badawy, "Automatic License Plate Recognition (ALPR): A State-of-the-Art Review," in IEEE Transactions on Circuits and Systems for Video Technology, vol. 23, no. 2, pp. 311-325, Feb. 2013, doi: 10.1109/TCSVT.2012.2203741.
- [3] R. Laroca et al., "A Robust Real-Time Automatic License Plate Recognition Based on the YOLO Detector," 2018 International Joint Conference on Neural Networks (IJCNN), 2018, pp. 1-10, doi: 10.1109/IJCNN.2018.8489629.
- [4] Vishal Jain, Zitha Sasindran, Anoop Rajagopal, Soma Biswas, Harish S Bharadwaj, K R Ramakrishnan, "Deep Automatic License Plate Recognition System," ICVGIP 2016 Proceedings of the Tenth Indian Conference on Computer Vision, Graphics and Image Processing, December 2016, Article No.: 6, Pages: 1-8, doi: 10.1145/3009977.3010052
- [5] N. Saleem, H. Muazzam, H. M. Tahir and U. Farooq, "Automatic license plate recognition using extracted features," 2016 4th International Symposium on Computational and Business Intelligence (ISCBI), 2016, pp. 221-225,
- [6] Shi, X., Zhao, W., Shen, Y. (2005). Automatic License Plate Recognition System Based on Color Image Processing. In: , et al. Computational Science and Its Applications – ICCSA 2005. ICCSA 2005. Lecture Notes in Computer Science, vol 3483. Springer, Berlin, Heidelberg.
- [7] Falguni Verma, Firoz Khan, Farhan Gupta, Faisal Johri, Fiza Patel. Robust vehicle number plate detection and recognition system based on image analysis techniques
- [8] Wadare, Kiran & Sharma, Mr & Patil, Mrs. Sheetal & Bewoor, Mrs. Mrunal & Pawar, Avinash & Kadam, Amol & Patil, Suhas. (2023). Vehicle Number Plate Detection using YoloV8 and EasyOCR.
- [9] Rudregowda, Shashidhar & Manjunath, A S & Kumar, R & Roopa, Munibyarappa & S B, Puneeth. (2021). Vehicle Number Plate Detection and Recognition using YOLO- V3 and OCR Method. 1-5. 10.1109/ICMNWC52512.2021.9688407.
- [10] Al-batat R, Angelopoulou A, Premkumar S, Hemanth J, Kapetanios E. An End-to-End Automated License Plate Recognition System Using YOLO Based Vehicle and License Plate Detection with Vehicle Classification. Sensors. 2022; 22(23):9477. <https://doi.org/10.3390/s22239477>
- [11] S. S. Patil et al., "Vehicle Number Plate Detection using YoloV8 and EasyOCR," 2023 14th International Conference on Computing Communication and Networking Technologies (ICCCNT), Delhi, India, 2023, pp. 1-4, doi: 10.1109/ICCCNT56998.2023.10307420.
- [12] M. H. Tutar, M. T. Bhuiya, M. S. Hossain, A. Tabassum and R. Khan, "Real Time Bangla License Plate Recognition with Deep Learning Techniques," 2022 IEEE International Conference on Artificial Intelligence in Engineering and Technology (IICAIET), Kota Kinabalu, Malaysia, 2022, pp. 1-6, doi:10.1109/IICAIET55139.2022.9936764.
- [13] J. -P. Kuska et al., "Image Registration of Differently Stained Histological Sections," 2006 International Conference on Image Processing, Atlanta, GA, USA, 2006, pp. 333-336, doi: 10.1109/ICIP.2006.313161.
- [14] Wang, P., Wu, Z., Zhang, S. et al. A GPU-free license plate detection based on fused color-edge and Retina approach. Multimed Tools Appl 83, 18649–18666 (2024). <https://doi.org/10.1007/s11042023-16216-w>
- [15] P. Kuska et al., "Image Registration of Differently Stained Histological Sections," 2006 International Conference on Image Processing, Atlanta, GA, USA, 2006, pp. 333-336, doi: 10.1109/ICIP.2006.313161.
- [16] A Karthikeyan, S Jothilakshmi and S Suthir, "Colorectal cancer classification based on deep ensemble model with self-adaptive training model", International Journal of Biomedical Engineering and Technology, 44/ 4, pp. 367-396, 2024, <https://doi.org/10.1504/IJBET.2024.138065>
- [17] S Suthir et al., "Colorectal cancer detection based on convolutional neural networks (CNN) and ranking algorithm", Measurement: Sensors, vol. 31, 2024, doi: 10.1016/j.measen.2023.100976
- [18] A. Gupta, S. Sriram and V. Nivethitha, "Harnessing Diversity in Face Recognition: A Voting and Bagging Ensemble Approach," 2024 International Conference on Automation and Computation (AUTOCOM), Dehradun, India, 2024, pp. 249-255, doi: 10.1109/AUTOCOM60220.2024.10486188.
- [19] Sountharajan Sehar et al., "Towards reliable IoT communication and robust security: investigating trusted schemes in the internet of medical things using blockchain", Sci Rep, vol. 13, pp. 20671, 2023.
- [20] P. Joshi and N. V., "Deep Fake Image Detection using Xception Architecture," 2024 5th International Conference on Recent Trends in Computer Science and Technology (ICRTCST), Jamshedpur, India, 2024, pp. 533-537, doi: 10.1109/ICRTCST61793.2024.10578398.
- [21] S. S M, S. Sriram and N. V., "Comprehensive Study: Advancements in Parkinson's Disease Diagnosis with Data-Driven Insights and Machine Learning," 2024 International Conference on Communication, Computer Sciences and Engineering (IC3SE), Gautam Buddha Nagar, India, 2024, pp. 697-701, doi: 10.1109/IC3SE62002.2024.10593380