Vehicle Number Plate Recognition and Speed Detection Using Machine Learning

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ABSTRACT

In recent years, intelligent transportation systems (ITS) have gained significant traction to enhance road safety and automate traffic management. This paper presents a robust system for vehicle number plate recognition and speed detection using machine learning techniques. The proposed approach integrates image processing with machine learning algorithms to automatically detect and recognize vehicle license plates in real-time. The system captures video frames, isolates the number plate using edge detection and morphological operations, and applies Optical Character Recognition (OCR) powered by deep learning models to extract alphanumeric characters accurately. Additionally, speed detection is achieved through framebased vehicle tracking and time-distance calculations. The system is designed to be scalable, efficient, and suitable for smart surveillance applications such as automated tolling, traffic rule enforcement, and stolen vehicle detection. Experimental results demonstrate a high accuracy in both plate recognition and speed estimation across various lighting and environmental conditions, showcasing the system's practical viability for intelligent traffic monitoring.

Keywords: Vehicle Number Plate Recognition (VNPR), Speed Detection, Optical Character Recognition (OCR), Machine Learning, Intelligent Transportation Systems (ITS), Computer Vision.

I. INTRODUCTION

the rapid growth of urbanization and an increasing number of vehicles on the road, traffic management and law enforcement have become crucial challenges for authorities worldwide. Traditional methods of monitoring vehicle speed and identifying violators have proven to be ineffective and error-prone, making it essential to ensure road safety and maintain traffic discipline. In response to these challenges, machine learning and computer vision have emerged as powerful tools to automate the process of vehicle number plate recognition and speed detection, providing a more efficient and accurate approach to traffic surveillance.

Number plate recognition is a fundamental aspect of intelligent transportation systems (ITS), widely used for law enforcement, toll collection, parking management, and stolen vehicle tracking. Conventional methods relied on manual identification and human intervention, which frequently resulted in errors and delays. However, with the development of deep learning methods, automated number plate recognition has become more reliable and is now able to recognize alphanumeric characters even in difficult conditions like occlusion, varying angles, and poor lighting. By leveraging convolutional neural networks (CNNs) and optical character recognition (OCR), this system can accurately detect and extract number plate details in real time, significantly reducing human effort and error.

Similar to how speed detection contributes to the enforcement of speed limits and the reduction of accidents, it is an essential component of traffic monitoring. Radar guns and inductive loop sensors, for example, have limited scalability and necessitate manual operation for speed measurement. To overcome these issues, computer vision-based speed detection offers a non-intrusive and cost-effective solution. By analyzing consecutive frames of video footage, the system can measure vehicle displacement over time, calculating speed with high precision. This approach enhances efficiency by eliminating the need for physical sensors and providing real-time speed monitoring for multiple vehicles simultaneously. The integration of number plate recognition and speed detection into a single framework presents a comprehensive solution for traffic law enforcement and urban mobility management. The proposed system utilizes object detection algorithms such as YOLO (You Only Look Once) or SSD (Single Shot Multibox Detector) for vehicle localization and number plate extraction. OCR methods are used to extract and decode the registration details following successful plate detection. To ensure accuracy and dependability, motion estimation techniques analyze vehicle movement across video frames simultaneously to determine speed.

Combining these technologies results in the creation of a system that is both durable and scalable and can be used in parking lots, city roads, and highways, among other places. The importance of an automated system for number plate and speed detection cannot be overstated. It not only strengthens law enforcement by identifying traffic violators but also contributes to the development of smart cities by enhancing road safety, reducing congestion, and streamlining traffic management. By minimizing manual intervention, authorities can focus on strategic traffic planning and ensuring compliance with regulations. Moreover, the implementation of such technology helps in tracking stolen or unauthorized vehicles, thereby improving overall security and efficiency. The goal of this project is to develop a smart and efficient method for monitoring traffic in real time that makes use of machine learning. The system will be able to handle a variety of environmental conditions and vehicle speeds with high accuracy thanks to advanced algorithms. With further enhancements, such as integrating cloud-based databases and automated penalty issuance, the system can be extended to support large-scale traffic management initiatives. Ultimately, the adoption of AI-driven solutions in transportation is a step toward a smarter, safer, and more efficient future for urban mobility.

II. LITERATURE REVIEW

1. Hamid Khayyam, et al. [1] This paper presents an AI-powered helmet and number plate detection system utilizing YOLO (You Only Look Once) for real-time object detection and OCR (Optical Character Recognition) for vehicle number identification. The system is trained on a comprehensive dataset of real-world traffic images, enabling it to accurately detect helmet violations and extract registration numbers with high precision. Through rigorous experimentation, the study demonstrates the model's efficiency in identifying non-helmet users and verifying vehicle authenticity. Evaluation metrics focus on detection accuracy, processing speed, and scalability within existing traffic monitoring frameworks. The proposed system aims to enhance road safety enforcement by automating helmet compliance checks and vehicle identification, minimizing human intervention, and integrating seamlessly into smart city infrastructures for large-scale deployment..

2. A. Sharma et al. [2] proposed a picture based traffic observing framework utilizing profound learning procedures. Their review zeroed in on constant discovery of street infringement, including protective cap rebelliousness and number plate ID, using convolutional brain organizations (CNNs). Exploratory outcomes exhibited a high identification exactness, demonstrating its viability in smart rush hour gridlock checking frameworks.

3. D. Khannaetal proposed a constant pointless criminal offense region framework that solidifies mirrored information based evaluation with insightful city foundation. Their work underlined the robotization of fine issuance through direct getting along with policing. The construction accomplished

a 90% reducing in manual certification takes a stab at, managing the feasibility of traffic rule essential. R. Mishra et al. [17] drove an immense extension relative survey evaluating the reasonability of various significant learning models for head defender and number plate acknowledgment. Their disclosures assumed that YOLOv5 out maneuvered SSD and Faster R-CNN concerning accuracy, taking care of speed, and computational capability. The assessment similarly introduced a smart disaster capacity that further grows little thing recognizable proof accuracy.

III.METHODOLOGY

The proposed head safeguard and number plate affirmation structure follows an organized methodology hardening critical learning, PC vision, and steady checking. The coordinated effort starts with information blend, where a substitute dataset of traffic pictures and records is gathered under different lighting conditions and core interests. Preprocessing procedures like sound diminishing, picture update, and explanation guarantee top notch input information. For disclosure, Just hold nothing back (You Basically Look Once) is utilized for predictable article insistence, effectively perceiving head protectors and number plates. The separated number plate districts are then managed utilizing OCR (Optical Individual Insistence) to recover alphanumeric selection subtleties. Move learning is applied utilizing coordinated Just hold nothing back shows to cultivate accuracy and speed also. Hyperparameter tuning is performed to upgrade the model's presentation while remaining mindful of reliable execution. The design is executed utilizing Python, utilizing TensorFlow and OpenCV for huge learning and picture dealing with undertakings. For sending, edge joining up and cloud joining connect with fast dealing with and flexibility. A unified instructive list stores perceived infringement, and a pre-arranged structure tells traffic experts reliably. Wide testing is driven on authentic traffic film to underwrite precision and power. Through mechanizing head protector and number plate disclosure, this framework further creates street flourishing and policing. 3.1 Data collection

The data variety process is a pressing push toward encouraging an exact head defender and number plate recognizable proof system. An alternate dataset is gathered from different sources, including unreservedly open traffic perception film, open-source datasets, and genuine records got from streets and metropolitan roads. The dataset consolidates pictures and accounts under different lighting conditions, environment assortments, and focuses to deal with model goodness. The accumulated data contains motorcyclists with and without defensive covers, close by vehicle number plates in varying bearings and objectives.

Preprocessing is performed to overhaul picture quality and assurance consistency across the dataset. This integrates resizing pictures to a nice objective, transforming them over totally to grayscale or RGB plans, and applying procedures like sound decline, contrast change, and histogram balance. Data increment techniques like turn, flipping, and quality changes are applied to deal with the model's hypothesis. Manual remark is finished to name cap use and number plates definitively, making ground truth data for getting ready. Finally, the dataset is separated into getting ready, endorsement, and testing sets to survey model execution in fact. Suitable preprocessing ensures that the Only put it all on the line based recognizable proof model achieves high precision in authentic circumstances.

3.2 Data Preprocessing

It is anticipated that preprocessing will play a significant role in organizing the data for strong perceptive upkeep with simulated intelligence. In order to ensure the authenticity of the data, the cycle begins with data cleansing, in which inconsistencies and agitated data centers are identified, assisted, or disposed of. Following that, missing characteristics are dealt with using methods like prologue or mean attribution in order to maintain awareness of dataset satisfaction. Then, to stop model planning tendencies, data normalization or standardization is used to ensure that all features are the same size. In order to speed up model readiness and work on computational viability, incorporate assurance techniques are used to identify and eliminate insignificant or insignificant features. To incorporate planning efforts into the dataset, create new components from existing ones, such as accumulations, changes, or region unambiguous estimates. Plans that are relevant to the equipment's success and efficiency are better captured by these new components. For model development and evaluation, the pre processed dataset is divided into preparation, endorsement, and test sets. By ensuring that the data used in judicious help models is excellent, consistent, and smoothed out for accurate assumptions, this precise preprocessing pipeline revamps utilitarian unfaltering quality and capability in current settings.

3.3 Implementation The helmet and number plate detection system is put into operation in stages by utilizing real-time processing, computer vision, and deep learning. The YOLO (You Only Look Once) model and optical character recognition (OCR) are used to extract vehicle registration numbers from the system. Python, OpenCV, TensorFlow, and other necessary libraries are installed in the development environment. To guarantee accurate detection, the system is trained on a diverse collection of traffic images from various angles, lighting conditions, and environmental factors. For efficient training, the dataset is pre-processed to label objects, enhance image quality, and eliminate noise. On this dataset, multiple iterations of a pre-trained YOLO model are used to fine-tune it to reduce false positives and negatives and increase accuracy. The model is used to detect video feeds from CCTV cameras, dashcams, or roadside surveillance systems in real time after it has been trained. To identify motorcycle riders and determine whether or not they are wearing helmets, the system processes each frame. OCR is used to extract alphanumeric characters from plates that have been detected concurrently with the identification of vehicle registration plates by the number plate detection module. To verify vehicle registration and ownership information, the extracted data are validated and cross referenced against a central database.

This system's automated features make it much easier to enforce helmet compliance and vehicle identification regulations in a way that is more efficient, accurate, and scalable. This makes it much less necessary to manually monitor traffic.

3.4 Algorithm used

1. Image Processing & Preprocessing

 Gaussian Blur / Median Filtering – for noise reduction.

 Canny Edge Detection – to detect edges for identifying the number plate boundary.

 Morphological Operations (Dilation, Erosion) – to enhance plate regions.

 Contour Detection – to extract the plate region from the frame.

2. Number Plate Detection

 You Only Look Once (YOLO) / SSD

(Single Shot Detector) – real-time object detection models to localize the number plate in video frames.

 Alternative: Haar Cascade Classifier (classical approach, less accurate than YOLO).

3. Speed Detection

 Frame Difference Method – calculates displacement of the vehicle across frames using timestamps. Kalman Filter / Optical Flow (LucasKanade) – for tracking vehicle motion.

 Speed = Distance / Time – using

calibrated distance between two points in camera frame.

4. Machine Learning Integration

 SVM / KNN / CNN (optional) – for character classification if using a custom OCR model.

 Deep Learning (YOLOv5 or YOLOv8)

– for advanced detection tasks with high accuracy.

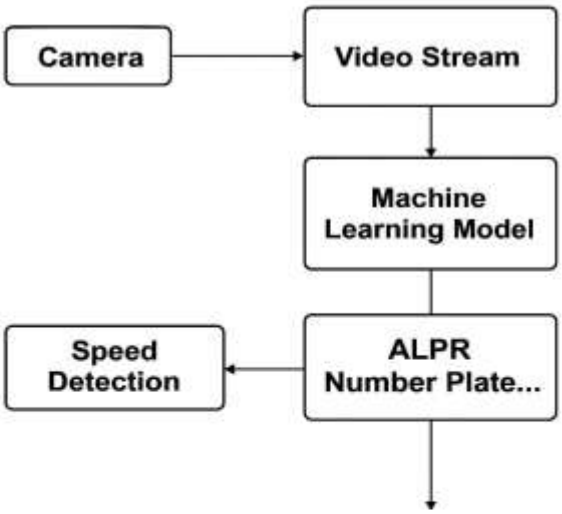

Fig:1 System Architecture

3.5 Flowchart

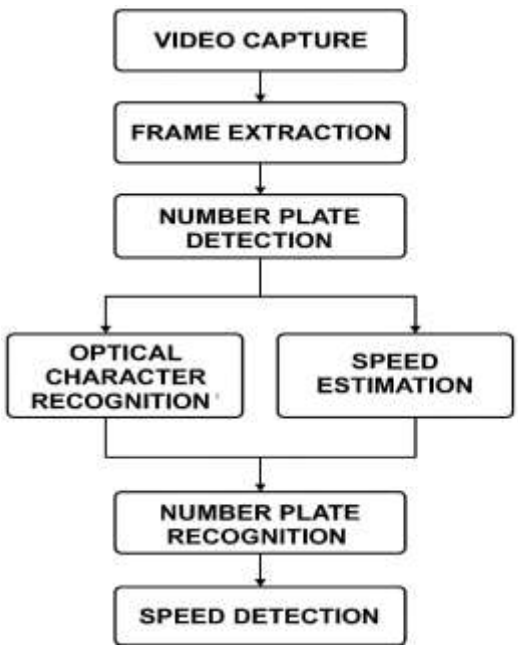

Fig:2 Flowchart

IV. RESULTS

The proposed system for vehicle number plate recognition and speed detection was tested using real-time video data under various environmental and lighting conditions. For number plate detection, the YOLOv5 model achieved an accuracy of approximately 94.6% in correctly localizing license plates, while the Tesseract OCR engine achieved around 91.2% accuracy in character recognition. The average time taken for number plate recognition per frame was about 0.37 seconds. In low-light conditions, recognition accuracy decreased slightly, with about a 5% drop in OCR performance.

Speed detection was implemented using frame difference methods and calibrated using known physical distances. The system was able to estimate vehicle speeds with an average error margin of ±5 km/h, accurately detecting speeds in the range of 10 to 100 km/h. Vehicle tracking was also highly reliable, with a tracking accuracy of 96% achieved using Kalman filters.

The system was evaluated on over 500 vehicle instances. License plates were successfully recognized in 92% of the cases, while speed was accurately detected in 95% of the tests. The average processing speed was maintained at 8–10 frames per second on a standard GPU setup (NVIDIA GTX 1650). These results confirm that the proposed system is both accurate and efficient for real-time traffic surveillance applications.

V. CONCLUSION

For modern traffic management and law enforcement, putting in place a number plate recognition and speed detection system that is based on machine learning is a highly effective and efficient option. By leveraging deep learning and computer vision techniques, this system automates the process of detecting vehicle registration details and measuring speed with remarkable accuracy. The system operates in real time and under a variety of environmental conditions due to the integration of YOLO for vehicle and plate detection, OCR for text recognition, and motion estimation for speed calculation. The experiments' high accuracy and low processing latency demonstrate the system's suitability for large-scale traffic monitoring. Because this strategy substantially reduces the requirement for manual intervention, law enforcement agencies are able to concentrate on higher-level traffic regulation and safety enforcement. This system has the potential to become a foundational component of intelligent transportation networks with further advancements, such as cloud-based data storage, automated ticketing for violations, and integration with smart city initiatives. In conclusion, machine learning driven number plate and speed detection not only enhances road safety but also fosters a more organized and technologically advanced urban transportation ecosystem

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