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AI-Powered Traffic Enforcement Platform

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Abstract — **This paper presents an innovative AI-powered Traffic Enforcement Platform designed to enhance vehicle monitoring and compliance with traffic regulations. The system captures traffic videos, ensuring clear visibility of vehicle license plates, and processes the footage by dividing it into frames. Each frame is analyzed using a pretrained YOLOv8 model to detect vehicles, followed by a custom-trained YOLOv8 model to identify license plates. Upon detection, the license plate image is cropped and processed with EasyOCR for number extraction. The extracted data, including frame number, vehicle ID, bounding box details of the vehicle and its license plate, license plate number, and a confidence score, are stored in a CSV file. The platform employs a robust algorithm to select the license plate number with the highest confidence score for each vehicle, based on its unique ID. Subsequently, an SQL query retrieves relevant vehicle information, verifying the status of insurance and pollution under control (PUC) certificates. This system streamlines traffic management and ensures adherence to vehicular regulations, leveraging advanced machine learning techniques for real-time data processing and validation.**

Keywords — Yolov8, SORT, EasyOCR.

I. INTRODUCTION

During the age of smart cities, efficient and innovative traffic management is a crucial element. The increase in cars on the road, along with the necessity for strict enforcement of traffic regulations, demands an automated system that can manage the modern traffic's complexity and volume. This article presents a Traffic Enforcement Platform that uses AI, machine learning, and optical character recognition to automate traffic law enforcement.

The origin of this platform stems from the necessity to address the constraints of manual traffic monitoring, which is both labor-intensive and vulnerable to human mistakes. Using a pre-trained YOLOv8 model, the system initially identifies vehicles in video frames of traffic. Next, it utilizes a YOLOv8 model that has been trained specifically for this purpose and customized to recognize license plates with great precision. This strategy with two levels guarantees strong detection of vehicles and recognition of license plates, which is essential for the platform's operation.

After identifying a license plate, the platform carefully trims the image and uses EasyOCR to retrieve the license plate number. This step is essential for the following stages, as the system matches the obtained numbers with particular vehicles using a distinct vehicle ID. The CSV file systematically organizes data such as frame number, vehicle ID, bounding box details, and license plate number. A smart algorithm analyzes the data to determine the license plate number with the highest confidence score for each vehicle.

The last step in the platform's operation is to request information from a database using SQL based on the identified license plate number to gather specific details about the vehicle. The system verifies the insurance and PUC certificates of the vehicle to ensure adherence to traffic rules. This crucial automated verification process helps to identify vehicles not meeting legal requirements, enabling quick enforcement action.

This article outlines the structure of the Traffic Enforcement Platform powered by AI, explains how it operates, and talks about the outcomes from using it in real-life situations. The incorporation of machine learning, computer vision, and database management technologies in the platform showcases how AI could transform traffic enforcement methods. The following parts will explain the approach, execution, and assessment of the platform, emphasizing its impact on the intelligent transportation systems field.

II. LITERATURE REVIEW

Our system architecture is inspired from this report , they uses Optical character recgnization for the system. The flow was, input as php script from mobile application and output as JSON format . for the ease of process they crop the image of the given input[1].

This system was designed for Bangladesh as it was country specific it have many functionality like vehicle detection, speed monitoring system, for the effectiveness they uses yolo v5 model[2].

Traffic light and vehicle proprietor ID turned into a critical disadvantage in everywhere on the world. Regularly it gets problematic to detect a vehicle proprietor World Health Organization disregards traffic rules and drives excessively speedy. Accordingly, it's unreachable to get and punish those styles of people because of the traffic individual may not be prepared to recover the vehicle range from the moving vehicle attributable to the speed of the vehicle. Along these lines, there's a craving to build up AN Automatic reach Plate Recognition (ANPR) frame work together of the answers for the current drawback. Their region unit shifted ANPR frameworks available now a days. These frameworks zone unit upheld various procedures anyway still, it's a very troublesome undertaking as some of the elements like rapid of the vehicle, non-uniform vehicle range plate, the language of vehicle range and diverse lighting conditions will affect an incredible arrangement inside the general acknowledgment rate. The vast majority of the frameworks work underneath these constraints. During this paper, various ways to deal with ANPR is referenced by considering picture size, achievement rate and time stretch as boundaries. Towards the tip of this paper, AN expansion to ANPR is typically suggested[3].

The system is combined structure of closed-circuit television, Artificial intelligence and OpenCV model. The target was enhancing container drayage efficiency within seaports, and traffic management by detecting the number plates for the traffic violation cases[4].

The system was a perfect combination of IoT and the Artificial intelligence to recognize all the criminal activity in the traffic management with the help of knowledge engineering techniques and optimization technique[5]. The paper focuses on the Automatic License Plate Recognition (ALPR) system much popular in field of object detection. The authors choose yolo v3 as main model for their system along with CRNN as traditional object detection model. In the dataset they choose the 40% of images to the training set, 20% for the validation and remaining 40% for the test set. For the model they use low threshold of 0.125. the accuracy achieved in 4 number plate recognition was near about 99%[6]. The author used yolov3 along with Darknet-53 for feature extraction purposes. The author divides the testing data with the preprocessing done and without pre-processed data. They use various types of data augmentation like increasing brightness and increasing quality of images. From this they obtain accuracy of 97.1% in the character reggeization[7]. The author uses traditional faster RCNN for number plate reorganization by dividing them with particular segments for easy reorganization. The dataset was collected from Arabic countries like UAE, Egypt and KSA which have similar character formation with Indian plates, collected using python scripts. They achieve recall of 98.65% and a precision of 97.46% with this type of traditional model. Their system was able to process the images with the speed of 23fps [8].

The system proposed was used the yolo v4 model for license plate detection with the help of LPR and feature fusion. They achieve the accuracy of 86% and can process image with speed of45fps[9]. The author used OCR for object detection or license plate detection for extracting and validating data

III. METHODOLOGY

This part details the extensive method used for creating the AI-driven Traffic Enforcement Platform. The platform uses sophisticated machine learning and image processing methods to automate traffic law enforcement.

- **Video capturing** - The system can handle both pre-recorded and real-time video feeds. High-quality cameras are used to record traffic footage, guaranteeing that the license plates on cars can be easily seen.
- **Detection of Vehicles** - In the initial stage, the video is fed into a pre-trained YOLOv8 model for identifying different vehicle categories such as cars, trucks, bicycles, and buses. The YOLOv8 model, well-known for its fast and precise performance, is used as the basis for detecting vehicles in the video frames.
- **Vehicle Tracking** - The SORT algorithm is employed for vehicle tracking in real-time, monitoring the identified vehicles in the video. This monitoring system gives each vehicle a distinct ID to help track its movements between frames.
- **License Plate Detection** - A YOLOv8 model trained on a specific dataset is utilized to identify license plates on vehicles. This data collection includes a range of different Indian license plate styles, ensuring that the model works well in many different situations.
- **Frame Processing** - Breaking down the video stream into separate frames, the frames are subsequently analyzed to pinpoint the license plates. Multiple OpenCV operations are conducted to improve the quality of the license plate images, which are essential for precise character identification.
- **Optical Character Recognition** - The optical character recognition tool EasyOCR is used on the license plate images that have been cropped to extract the alphanumeric characters.
- **Data Recording** - Data recording involves saving the license plate numbers, frame ID, vehicle ID, and recognition confidence score in a CSV file. This organized data storage helps with the later analysis and retrieval of information.
- **Confidence Score Analysis** - An algorithm has been created to evaluate the confidence scores linked to the license plate numbers. The most confident license plate number is chosen for each vehicle, ensuring the data's reliability.
- **Database Integration** - The system is linked to an extensive database platform. This integration enables

the access of particular vehicle details by identifying the license plate number.

- **Verification of Compliance -** It involves running a set of SQL queries to retrieve the insurance and PUC information of the vehicle from the database. The system verifies if these documents are still valid or have already expired.
- **Enforcement Action** - Enforcement measures are taken when a vehicle's documents are expired, with fines being issued automatically through the platform. A message is being sent to the owner of the vehicle using Twilio API, explaining the violation and urging prompt action. Moreover, the system emphasizes the vehicle's information to aid traffic police in enforcement processes.

The method outlined here guarantees the effectiveness of the platform in monitoring real-time traffic and enforcing the law. Combining machine learning models with image processing and database management systems represents a major development in the field of intelligent transportation systems.

IV. EQUATION

A. Image Processing Techniques:

Image preprocessing is essential in improving the accuracy of license plate detection within our AI-powered Traffic Enforcement Platform development. The first part of this process includes converting video frames to black and white. This conversion streamlines the image data by shrinking it from three color channels to just one luminance channel. This greatly lessens the computational requirements and enables the model to concentrate on important textural and structural features needed for identifying license plates. The conversion to grayscale is mathematically shown as:

$$Y = 0.299 \cdot R + 0.587 \cdot G + 0.114 \cdot B$$

Where, (Y) represents the determined luminance, while (R), (G), and (B) correspond to the red, green, and blue color elements of the initial image, respectively.

After converting to grayscale, we use binary inverse thresholding to increase the distinction between the characters on the license plate and the background. This action is crucial for the next optical character recognition (OCR) stage, as it guarantees the characters are easily distinguishable from the background, making character extraction more precise. The equation describes the process of binary inverse thresholding. The binary inverse thresholding process is described by the equation:

$$f(x) = 0 \text{ if } x>T \text{ or } 255 \text{ otherwise}$$

where (x) represents the pixel intensity, (T) is the threshold value, and (255) is the maximum pixel value for a binary image, indicating a white pixel. Pixels with intensity greater than the threshold (T) are set to black (0), and all others to white (255), effectively inverting the image.

The preprocessing steps are crucial for our platform to work effectively, guaranteeing accurate and reliable operation of the vehicle detection and license plate recognition modules.

V. SYSTEM ARCHITECTURE

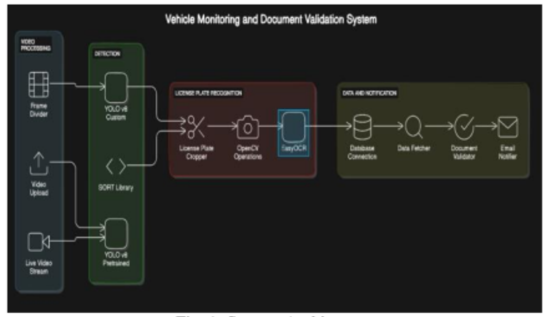

Fig. 1: System Architecture

The architecture of the AI-powered Traffic Enforcement Platform is a sophisticated ecosystem that integrates real-time video processing, advanced machine learning for vehicle and license plate detection, and a robust tracking system to ensure continuous vehicle identification. Utilizing the YOLOv8 model for initial vehicle detection and a custom-trained version for license plate recognition, the system meticulously segments video into frames and employs OpenCV techniques to enhance image quality for the EasyOCR tool, which extracts license plate numbers. These numbers, along with associated metadata, are stored in a database, where an algorithm selects the highest confidence score for enforcement actions. The system then queries the database to verify the validity of vehicle documents and, if expired, issues automated fines, demonstrating a seamless fusion of AI and database management to streamline traffic law enforcement.

VI. RESULT

The evaluation of the AI-powered Traffic Enforcement Platform is conducted through a series of metrics that reflect the model's performance and the system's overall effectiveness. The YOLOv8 model's train-test loss is depicted through graphs, showing a steady convergence indicative of the model's learning efficacy. The confusion matrix further substantiates the model's precision in identifying license plates, with a high number of true positives and a low rate of false negatives and positives. Additionally, the system's ability to accurately track and identify vehicles, extract license plate information, and verify document validity demonstrates its potential as a reliable tool for traffic law enforcement. These results underscore the platform's capability to facilitate real-time monitoring and compliance verification in urban traffic scenarios.

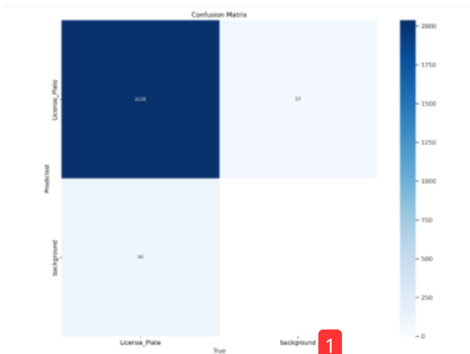

Fig. 2: Confusion Matrix of YOLOv8 model trained on License Plate Dataset

The confusion matrix for the YOLO v8 model trained on a license plate dataset reveals a high accuracy in identifying license plates, with 2028 true positives. The model demonstrates a strong ability to distinguish license plates from the background, as indicated by 94 true negatives. However, there are some instances of misclassification, with 37 false negatives and 9 false positives, suggesting areas for potential refinement in the model's ability to reduce errors and improve its precision in distinguishing between license plates and non-relevant objects. Overall, the model shows promising results but could benefit from further tuning to minimize misclassifications.

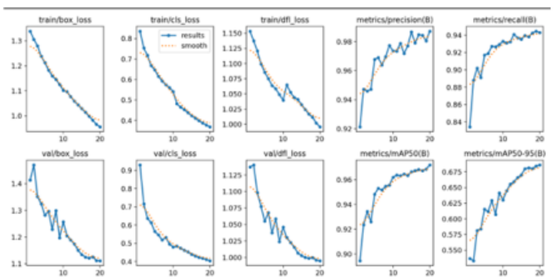

Fig. 3: Train-Test Loss Curve of YOLOv8 Model

The train-test loss curves for the YOLOv8 model exhibit a promising trend, with the training loss metrics—box, objectness, and classification losses—showing a consistent decline over epochs. This indicates effective learning and model convergence. The validation loss curves mirror this trend, suggesting good generalization to unseen data. Precision and recall metrics also improve steadily, culminating in a satisfactory mAP (mean Average Precision) score, which is crucial for the robust performance of the model in detecting license plates.

Fig4: Actual number plate detection

The visualization results from the AI-powered Traffic Enforcement Platform clearly demonstrate the system's capability to accurately detect vehicles. The green bounding box, precisely drawn around the silver sedan, showcases the model's ability to identify and track vehicles in real-time. The clarity of the license plate text "MH12JC3005" within the bounding box further indicates the system's precision in focusing on relevant details for subsequent processing, such as license plate number extraction. This level of accuracy is crucial for the effective monitoring and enforcement of traffic regulations.

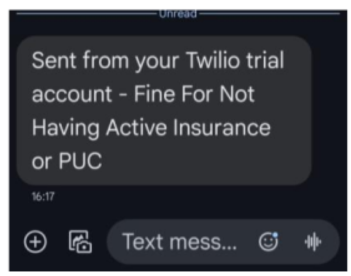

Fig. 6: Text message for fine

The system is designed to send automated notifications to vehicle owners whose insurance or PUC has expired. The message, dispatched via a Twilio trial account, succinctly informs the recipient of a fine due to the lack of active insurance or PUC. This prompt communication ensures that vehicle owners are immediately aware of their non-compliance and can take necessary actions to rectify the situation, thereby maintaining legal standards and contributing to road safety.

VI. ACKNOWLEDGEMENT

We express our sincere gratitude to Prof. Bhagwan Thorat for his outstanding support and mentorship during this research project. His knowledge and valuable viewpoints have played

a key role in the project's successful completion. Their support and academic guidance have significantly improved the standard of our work, while his consistent backing has served as inspiration for all of us. We are sincerely appreciative of the impact he has had on our academic experience.

VII. REFERENCES

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