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Real-Time License Plate Recognition and Alert System

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ABSTRACT:

The advent of deep learning has revolutionized computer vision, enabling real-time analysis crucial for traffic management and vehicle identification. This research introduces a system combining vehicle make and model detection with Automatic Number Plate Recognition (ANPR), achieving a groundbreaking 97.5% accuracy rate. Unlike traditional methods, which focus on either make and model detection or ANPR independently, this study integrates both aspects into a single, cohesive system, providing a more holistic and efficient solution for vehicle identification, ensuring robust performance even in adverse weather conditions. The paper explores the use of deep learning techniques, including OpenCV, in combination with Python programming language. Leveraging MobileNet-V2 and YOLOx (You Only Look Once) for vehicle identification, and YOLOv4-tiny, Paddle OCR (optical character recognition), and SVTR-tiny for ANPR, the system was rigorously tested at Firat University's entrance with a thousand images captured under various conditions such as fog, rain, and low light. The system's exceptional success rate in these tests highlights its robustness and practical applicability. Additionally, experiments evaluate the system's accuracy and effectiveness, using Gradient-weighted Class Activation Mapping (GradCam) technology to gain insights into neural networks' decision-making processes and identify areas for improvement, particularly in misclassifications. The implications of this research for computer vision are significant, paving the way for advanced applications in autonomous driving, traffic management, stolen vehicles, and security surveillance. Achieving real-time, high-accuracy vehicle identification, the integrated Vehicle Make and Model Recognition (VMMR) and ANPR system sets a new standard for future research in the field.

INDEX TERMS: License plate recognition, deep learning, Open CV, human machine interface.

I. INTRODUCTION:

Nowadays, with technology doubling in every phase of life, the services are obviously getting better using such technologies Technology is also playing an important factor in the vehicle transport system. The automobile transportation system plays a primary task in the monitoring of traffic, crime detection system, tracking stolen vehicles, and protection applications. The quantity of active vehicles has drastically increased, leading to more illegal activities. The rapid proliferation of vehicles makes it difficult to track them, highlighting the importance for relevant authorities to do so. As the flow of vehicles grows daily, there is a heightened need for automatic number plate detection and vehicle make and model identification. This tool is also valuable for monitoring vehicle speeds, especially in light of the serious accidents that occur each year. The UK police first recognized the Automatic Number Plate Recognition (ANPR) system in 1976, and its prevalence has significantly increased in the last decade. Along the highway, thousands of surveillance cameras are installed, primarily for traffic management and law enforcement. Continuous manual inspection would not be feasible, as such an approach would require colossal efforts, involving significant costs. Automatic visual interpretation offers the capability to detect, track, and classify all traffic. A particularly important concept in this context is make and model recognition (MMR). The make and model information of vehicles can be utilized to identify vehicles with stolen license plates by comparing the observed vehicle model with the registered information associated with the license plate. Another application is identifying specific vehicles after a crime when only a vehicle description is available without the license plate number. In such instances, the make and model of the vehicle need to be obtained visually. These challenges are the focal points of this paper. the Vehicle Make and Model Recognition (VMMR) or vehicle identification addresses the challenge of determining the make and model of a vehicle, that is, identifying the vehicle manufacturer's name and the specific product, when provided with an input image or video featuring the vehicle. In recent times, VMMR has increasingly become a crucial component of Intelligent Transportation Systems (ITS) and has attracted significant attention from the research community Make and model recognition provides important information in many applications such as traffic management, intelligent surveillance, traffic behaviour analysis, and traffic monitoring. For example, the VMMR technology is employed in the traffic cameras installed in toll stations for the automatic detection and recognition of passing vehicles. In traffic monitoring, the vehicle model recognition is used by ITS to build the vehicle flow statistics used for the analysing of real-time traffic conditions. In traffic security, the make and model recognition can help locate stolen vehicles The objective of this paper is therefore to solve the security and find the stolen car also mismatch and missing license plates cases with an accurate visual analysis system. To this end, we present an MMR system developed for the Turkey National Police, in which vehicles are observed from a camera mounted in an overhead sign structure on the highway, with the purpose to extract accurate make and model information. The extracted information may be combined with existing ANPR information.

Deep Learning – now evolved as an efficacious technique of handling big data – uses intricate algorithms and artificial neural networks to train machines/computers in such a manner that they may learn from experience, classify and recognize data/images just the way human brain does. For Deep Learning, in particular, a Convolutional Neural Network or CNN is an artificial neural network, used extensively for image/object recognition and classification. Thus, in the context of Deep Learning, objects within an image are essentially recognized using a CNN. CNNs have found broad applications in several tasks such as image processing problems, localization, and segmentation in computer vision tasks, video analysis to recognize obstacles in self-driving vehicles, speech recognition in natural language processing. As CNNs play a prominent role in such fast-growing and emerging areas, they are often used in Deep Learning.

The implications of this research for computer vision are substantial, laying the groundwork for sophisticated applications in various fields. In autonomous driving, it can enhance vehicle navigation and safety. For traffic management, car tracking, it offers the potential to optimize flow and reduce congestion. In the realm of stolen vehicle and security use cases among others, it improves tracking and identification capabilities. Additionally, in security surveillance, it bolsters the effectiveness of monitoring and threat detection systems. Grad-CAM was a key factor of both diagnosing and sense-making the models' misclassifications. In that sense, when Grad-CAM highlighted the region of the image in which focal point the model gave predictions, it became possible to diagnose the patterns in misclassifications. For example, sometimes reflections or occlusions were the reason for which the model failed to classify a vehicle or its license plate correctly. Grad-CAM visualizations helped in tempering the model's behaviour to be much robust towards such peculiarities

The proliferation of vehicle traffic in urban environments necessitates automated systems for vehicle identification and monitoring. Traditional manual methods are labor-intensive and prone to errors. Automatic License Plate Recognition (ALPR) systems reduce human intervention, increase throughput, and improve accuracy for applications such as border control, parking management, and law enforcement. This project focuses on designing and implementing a low-cost, high- accuracy ALPR system capable of real-time processing and alert generation via a web interface.

II. LITERATURE REVIEW:

In the last decade, with the advancement of information technology and the increase in population, numerous techniques for developing systems to detect vehicle make, model, and license plates have been devised and examined. The system for recognizing vehicles encompasses two primary phases: detection and classification, aimed at identifying and categorizing vehicles from a directly frontal perspective. In the initial detection phase, various methodologies are employed. Ren and Lan utilize frame differencing, while Prokaj and Medioni employ background subtraction techniques to ascertain the complete dimensions of the vehicle. Extensions to these detection methods have been made by Siddiqui et al.and Petrović and Cootes , who enhanced the system's capability through the integration of license-plate detection algorithms. Moreover, Wijnhoven and de With introduced the use of a Histogram of Oriented Gradients (HOG) for achieving detection that is robust to variations in lighting. Furthermore, Zhou et al. have contributed to this field with their research on leveraging Convolutional Neural Networks (CNN) for enhancing the precision of vehicle detection. Upon successful detection of a vehicle, the identified vehicular section within the image is subsequently processed for classification, specifically within the context of Make and Model Recognition (VMMR) . Deep learning has been extensively used in the field of object detection. One of the most common deep learning networks used for object detection is the CNN. Jerry Wei describes CNN as robust models that are easy to control and train and seldom overfit when trained on large image datasets. Significant computational power, however, is required to train CNNs on high-resolution images With much ongoing application and research, CNNs turn out to be well-suited for vehicle detection and recognition tasks. Xingcheng Luo et al. used a large image dataset and increased the layers in AlexNet to achieve vehicle and facial recognition accuracy of up to 97.51% and 91.22%, respectively. Hyo Jong Lee et al. . Extracted frontal views of vehicle images and fed them into SqueezeNet for training and testing. Albeit running on a desktop Central Processing Unit (CPU) with a powerful Graphical Processing Unit (GPU) setup, the study managed to achieve a 96.3% recognition accuracy with the inference tasks running at a mean of 108 ms. Their model also required less than 5 MB of space, making it broadly viable for real-time inference applications. The field of image classification has also been extensively documented. CNNs, or Convolutional Neural Networks, are currently the most advanced method for classifying images. They were first developed by LeCun et al. and got widespread recognition when Krizhevsky et al. utilized a CNN called AlexNet to obtain the highest performance in the 1000-class ImageNet Challenge. The user's text is MMR, a modified version of AlexNet, was developed by Ren and Lan to reach a 98.7% accuracy. This was accomplished by using 233 vehicle models in a dataset of 42,624 pictures. Yang et al. released the CompCar dataset, which comprises several perspectives of cars, including both internal and external components, as well as 45,000 frontal photos of 281 distinct car types. The study demonstrated that AlexNet achieves similar performance to the more contemporary Overfeat and GoogLeNet CNN models (98.0% compared to 98.3% and 98.4%, respectively). Siddiqui et al. demonstrated that the Bag of SURF features method achieves a 94.8% accuracy on a vehicle dataset consisting of 29 classes and 6639 images, specifically for small-scale classification challenges. Since its introduction by Krause et al. (2013), the Stanford Cars Dataset has been used as a standard for assessing MMR algorithms. It has a huge library of vehicle photos with thorough annotations, which makes deep learning model building and comparison easier . Writer Classification and Recognition of Car Images. This paper shows outcomes from experiments for the machine learning algorithm, Python modules, and deep neural network model built using Keras and TensorFlow for artificial vision classification of car pictures. Applications for image classification range from medical diagnostics to autonomous vehicles.

This research offers a thorough analysis of the state-ofthe-art ANPR systems and algorithms, contrasting how well they function in simulations and real-time testing. Through analysis of extraction, segmentation, and recognition methods and the provision of suggestions for future trends, the goal is to enhance ANPR technology, which is based on computer vision (CV) algorithms. Even with the finest algorithms, maximizing accuracy could require additional technology . The primary aim of this research is to examine the problems related to segmentation and recognition in the License Plate Recognition Framework and devise alternate solutions. The process consists of three stages: identifying and isolating the license plate section from a wider image, eliminating the alphanumeric letters from the surrounding background using the license plate region, and subsequently feeding them into an OCR system for identification. In order to accurately determine the identity of a vehicle using its license plate, it is necessary for the plate to be clearly visible in the image obtained by the acquisition system, such as a video or still camera. The user’s text is . In today’s congested traffic system, the automated license detecting system is essential. It assists in enforcing traffic laws by automatically monitoring them. India has a high rate of driver infractions and reckless driving, which makes it challenging for traffic police officials to determine specific car specifications. Through development and implementation throughout time, an automatic license detecting system has been created to streamline and accelerate traffic regulation surveillance on automobiles. An overview of the several methods for automatic license detection is given in this article . In the table 1 below show some comparation research with proposed method.

lll. RELATED WORK:

deep learning has significantly advanced the field of real-time license plate recognition (LPR) and alert systems. Early systems relied heavily on traditional image processing and optical character recognition (OCR), but these approaches often struggled with varying lighting conditions, angles, and plate formats. Modern approaches now employ convolutional neural networks (CNNs) and object detection models such as YOLO (You Only Look Once) for real-time detection of vehicles and license plates. For instance, Silva and Jung (2018) proposed a two-stage deep learning pipeline that uses YOLO for plate detection and a CRNN (Convolutional Recurrent Neural Network) for character recognition, achieving high accuracy in uncontrolled environments. Additionally, end-to-end models like LPRNet and transformer-based architectures have improved the robustness of character recognition, even in cases of motion blur or partial occlusion. These systems often integrate with real-time databases and use alert mechanisms via IoT protocols or cloud messaging services to notify authorities or users when a match is found against a list of flagged plates. The combination of high-speed detection, accurate recognition, and automated alerting has made deep learning-based LPR systems an essential component of smart surveillance, traffic monitoring, and law enforcement applications.

lV. EXISTING SYSTEM:

In the current scenario, individuals with Locked-in Syndrome (LIS) depend heavily on human assistance for communication. The most common method involves interpreting eye blinks or gaze patterns manually by nurses or caretakers. Some advanced systems use expensive eye tracking hardware or Brain-Computer Interface (BCI) devices, which are often costly, complex to operate, and not widely accessible. These systems, while functional, are not user-friendly for those who wish to operate them independently. The lack of affordable, autonomous solutions leaves many LIS patients with limited or no means of expressing their thoughts when human interpreters are not available.

Disadvantages of the Existing System:

1. Low accuracy in poor lighting or weather conditions.
2. Trouble reading damaged or fancy license plates.
3. Expensive to install and maintain.
4. Requires strong internet or network connection.

5. Privacy issues – may track people without consent.
6. Limited to known plates – can't detect unknown threats.
7. Can be hacked or misused if not secured properly.
8. Not easy to expand to new areas or add more cameras.

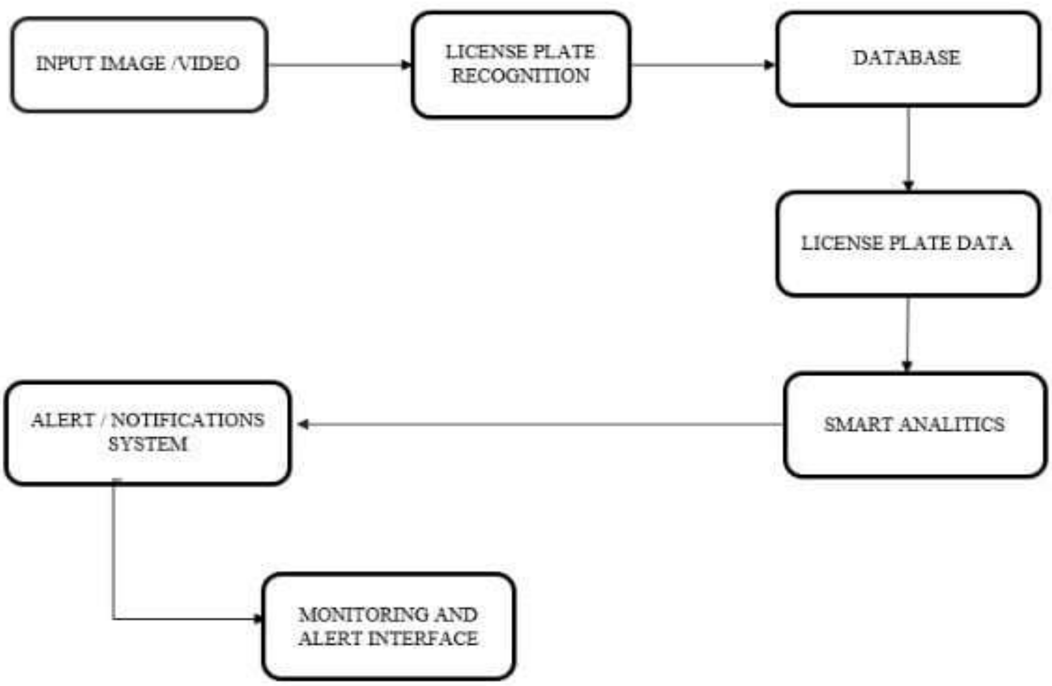
V. PROPOSED SYSTEM:

We Propose a fully loc al, edge -base d system that uses Easy OCR for reading characters and Flask as the backend. The user submits a target plate number via command -line argument. The system processes every frame of the video or camera feed, identifies text, checks for pattern validity, and alerts the frontend if the plate matches the given input.

Advantages of the Proposed System:

1. Higher accuracy using AI and deep learning.
2. Works in all conditions – day, night, rain, or fog.
3. Real-time alerts for fast response.
4. Cost-effective with edge computing (e.g., Raspberry Pi, Jetson Nano).
5. Improved privacy with encrypted data and access control.
6. Can detect unknown threats using smart analytics.
7. Easier to expand and integrate with existing systems.
8. User-friendly interface for monitoring and alerts.
9. Offline capability for areas with poor internet.
10. Secure and reliable with data protection features.

VI. ARCHITECTURE DIAGRAM:



VII. AUTOMATIC NUMBER PLATE RECOGNITION:

Automatic Number Plate Recognition employs optical character recognition technology to ascertain vehicle license numbers from images where these plates are detected. The system's precision is significantly influenced by the quality of the images captured. These images represent two-dimensional visual representations essential for the algorithm's operational effectiveness. Within such a frame, a vehicle can be imaged, and its license number can be accurately extracted, assuming the image is clear and free from obstructions or defects. The unique identification of a vehicle is achievable through its license plate. Following the image processing, the system generates the vehicle's details, prominently featuring the license . ANPR is a system that utilizes Optical Character Recognition (OCR) to recognize characters from various sources like surveillance cameras or other cameras. It is crucial to position the camera at the correct angle to capture the best and most precise image [49]. OCR analyzes each character separately. OCR is a method of transmitting written or printed information from any source, including written or printed documents and images, to a text decryption machine to obtain the desired source. It is a complex process that involves multiple algorithmic steps, such as uploading the image, detecting characters, adjusting them on the page, eliminating blurriness, and producing a final editable formatThe ANPR system leverages Optical Character Recognition (OCR) technology to identify characters captured by various imaging devices, including surveillance and other types of cameras. The accuracy of character recognition significantly depends on the strategic positioning of the camera to ensure optimal image capture [49]. OCR operates by individually analyzing each character, serving as a mechanism to convert written or printed content from diverse sources into machine-readable text. This conversion process is intricate, involving a series of algorithmic procedures that encompass image upload, character identification, spatial adjustment on the document, clarification of any blurred elements, and ultimately, the generation of an editable text format. OCR technology finds applications across diverse sectors, including commerce, industry, academia, security, literature, and healthcare, particularly in creating assistive devices for individuals with visual impairments. It plays a critical role in various applications, such as recognizing license plates, processing passports at airports, scanning barcodes in various institutions, and digitizing handwritten documents into electronic formats. The ANPR system incorporates distinct algorithms or sets of rules to process different segments of the license plate image. Nonetheless, the image processing phase encounters numerous challenges, such as image blur, inadequate lighting, obstructions, suboptimal camera angles, variability in fonts, and discrepancies across different jurisdictions, all of which can complicate the recognition process.

VIII. PROJECT DESCRIPTION:

Interfaces

Frame Acquisition: Captures frames using OpenCV Video Capture.

Detection &Recognition: Reads frames, applies grayscale conversion, adaptive thresholding, contour detection for candidate plates, EasyOCR for text extraction, and correction algorithms.

Web Interface: Flask app with endpoints /video feed, /plates, and /alerts; Jinja2 templates
for dynamic rendering.

License Plate Localization

Edge Detection (Canny): cv2.Canny to detect edges.

Morphological Operations: Dilation and erosion to close gaps.

Contour Detection: cv2.findContours to locate rectangular candidates.

Aspect Ratio Filtering: Retains contours with typical plate ratio (4:1 to 5:1).

Perspective Correction: cv2.getPerspectiveTransform to rectify plate region.

OCR and Correction

EasyOCR Integration:reader.readtext for initial text and bounding boxes.

Ambiguity Mapping: Map confusing characters (e.g., O↔0, S↔5).

Candidate Generation: Cartesian product of possible replacements, limited to 500 combinations.

Pattern Matching: Regex ^[A-Z]{2}[0-9]{1,2}[A-Z]{1,3}[0-9]{4}$ to validate plate strings.

Alert Generation

Timestamp Calculation: For video files, elapsed time from start; for camera, system time.

Thread-Safe Logging: Python threading. Lock ensures safe updates of detections and alerts lists.

lX. CONCLUSION AND FEATURES:

The Real-Time License Plate Recognition and Alert System demonstrates the practical integration of computer vision and machine learning technologies to enhance vehicle monitoring and security. By capturing and processing license plate data in real time, the system enables automated vehicle identification, streamlines law enforcement processes, and improves traffic management. The addition of an alert mechanism further strengthens its utility by enabling instant notifications for unauthorized or suspicious vehicles. This project lays a strong foundation for future advancements, such as integration with national databases, multilingual plate recognition, and enhanced accuracy under varying environmental conditions.

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