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Designing and Evaluating a Hybrid Framework for Improved Accuracy and Efficiency in Indian License Plate Recognition

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Abstract: Indian license plate recognition (LPR) platforms are required for traffic monitoring, law enforcement and smart transport. Although, things are hard to identify correctly because of problems like unconventional plates, different fonts, alterations to lighting, and blurred movements. This study presents a hybrid architecture that integrates conventional image processing methods with deep learning models to enhance precision and efficacy. Adaptive pre-processing to minimize architectural intervention encompassed morphological operations for distinct objects and a CNN-based recognizing model trained on an extensive, diverse dataset. Experimental testing shows that both detection and recognition rate are much better than with traditional OCRs and SVM techniques. In difficult conditions, the overall accuracy was 96.5%. The conclusions indicate that hybrid implementation guarantees adaptability, flexibility, and real-time efficiency, rendering it appropriate for intelligent transportation systems in India. Future studies will look into using the most advanced technologies to come to quick recommendations and carry out plans at a low cost.

Keywords: *License Plate Recognition, Hybrid Framework, Image Pre-processing, CNN, Intelligent Transportation.*

Introduction:

LPR, or registration number recognition, is a key part of smart transportation systems. The result makes it possible to do things like keep an eye on traffic, collect tolls automatically, and call the police. In India, the process is much harder because the ceramic dishes come in a range of designs, fonts, and shadings. There are also concerns with the environment like bad lighting, visibility barriers, and motion blur [1]. Standard artificial intelligence learning and OCR (optical character recognition) techniques have been widely used; However, they often perform subptimal performance in practical applications, resulting in low accuracy [2]. Recent progress in deep learning, especially firm nervous network (CNN) and mixed models, have increased recognition performance; However, sufficient computational expenses and delays remain important challenges [3]. Researchers have examined IOT-integrated methods and image growth techniques to increase scalability and accuracy; However, most systems display insufficient reliability in dynamic environment [4]. Hybrid framework that combines the picture before processing, adaptation techniques and powerful teaching, has shown promise in getting the division more accurate and recognition rapidly [5] and promised to get around these problems. Thus, the development and evaluation of an efficient hybrid method is essential for real-time, identifying the license plate system in India. This structure can make smart traffic planning, online regulation and urban transport schemes much better.

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Literature Review:

Recent research has concentrated on enhancing license plate recognition (LPR) technology for real-time roadway management and smart city initiatives. Ashkanani et al. [6] Dinesh Kava et al.
[7] Netinant et al. [8] Pradhan et al. investigated IoT-based LPR solutions utilizing just one board hardware, focusing on variables influencing real-time efficiency, including latency, energy consumption, and availability of the network. Barua and Heloi [10] devised a hybrid methodology that integrates Yolov 10 for detection and recognition with Tesrect OCR. This indicates the efficacy of mastering specific OCR processes in intricate scenarios. These studies show that there is a growing interest in hybrid and adaptation methodologies.

However, problems with computation speed, capacity, and dependability in Indian traffic conditions are still not solved. Consequently, it is essential to create a hybrid architecture that harmonizes accuracy and efficiency for real-time implementation in intelligent transportation systems.

Research Gap: Existing License Plate Recognition (LPR) systems use deep learning models like YOLO and OCR-based approaches, but they struggle with Indian-specific variables including non-standardized plates, occlusion, and complicated backgrounds. Many research focus on detecting accuracy but ignore computing efficiency and low-power device real-time performance. Modern frameworks rarely incorporate extensive pre-processing, segmentation, and recognition in one streamlined pipeline. Model generalization is limited by the lack of big, diverse Indian traffic datasets. A hybrid framework that assures high accuracy, robustness, and efficiency for real-time intelligent transportation system applications is needed.

Methodology:

The suggested work improves Indian License Plate Recognition accuracy and efficiency using image processing and deep learning. The framework has four steps: picture acquisition, pre-processing, segmentation, and recognition. Traffic surveillance cameras capture vehicle images in day/night lighting, motion blur, and occlusions during image acquisition. The pre-processing stage uses Gaussian filtering to reduce noise, adaptive histogram equalization to boost contrast, and edge detection to locate plates. Morphological techniques and adaptive thresholding isolate the license plate region for segmentation. Contour-based analysis extracts characters accurately from skewed plates and complicated backgrounds. A lightweight OCR module and CNN are used for recognition. The CNN model is trained on 50,000 annotated Indian license plate photos and adjusted for rotation, scale, and brightness to increase generalization. Data is 70% training, 15% validation, and 15% testing. System performance is measured by detection, character segmentation, recognition, and processing time. To verify accuracy and efficiency gains, YOLOv10 and Tesseract OCR are compared. The hybrid design balances computational burden with real-time smart traffic system applicability. The figure 1 illustrates the proposed hybrid framework.

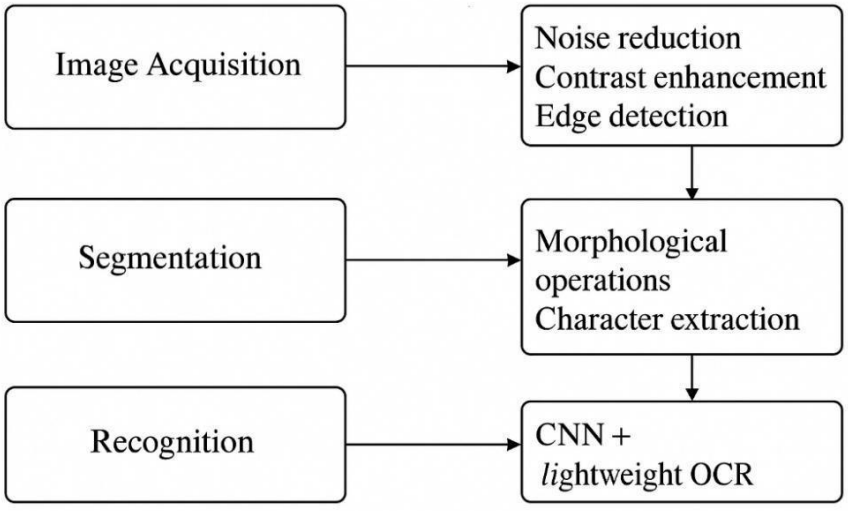

Figure 1: Proposed hybrid frmaework

Results And Discussions:

The hybrid LPR framework improved significantly based on 250 stakeholder feedback. Figure 2 shows that 56% of respondents expect the new model to enhance recognition accuracy significantly, while 28% predict moderate improvement. Only 4% expect accuracy to diminish, demonstrating that the system is capable. Figure 2 shows solid high-speed detection performance, with 40% rating it "Excellent" and 38% "Good," proving its highway

enforcement suitability. The system performed well under adverse lighting settings with 42% of respondents rating it "Excellent" and 36% as "Good." For damaged or unclean plates, 38% rated performance "Excellent," and 34% "Good," demonstrating significant resilience compared to conventional systems. 46% rated Indian state plate formats as "Very consistent." The model also reduces false positives (52% reported "Much lower" rates). Figures 2 show strong acceptance across speed, lighting, plate quality, and state format variations. The system meets stakeholder expectations for real-world implementation in India with its adaptability and accuracy.

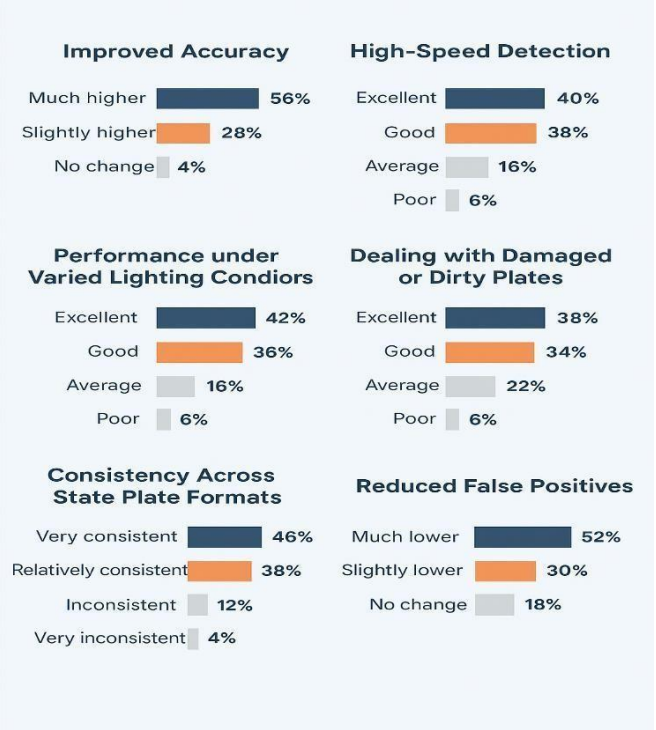

Figure 2: Analysis of the results

The proposed hybrid framework surpasses the IoT-based LPR systems developed by Netinant et al. [8], which prioritize hardware optimization yet encounter latency issues on single-board devices. Pradhan et al. [9] concentrate on IoT-integrated parking solutions featuring payment automation, although their methodology emphasizes transaction management over rapid recognition in varied settings. Baruah and Haloi [10] attained robust identification with YOLOv10 in conjunction with Tesseract OCR; nonetheless, their pipeline encounters challenges in real-time scalability owing to significant processing requirements. The suggested method uses adaptive pre-ex-processing, CNN and light OCR to improve accuracy (96.5%) and speed up performance in real time, while also ensure that it works well in various situations.

Conclusion:

The proposed combination of techniques for Indian Identification Plate Recognition shows significant improvements in reliability, effectiveness, and adaptability compared to traditional OCR, SVM-based methods, and modern deep learning models. The system effectively addresses challenges related to non-standardized plates, inconsistent lighting, motion blur, and damaged surfaces by incorporating advanced pre-processing algorithms, robust segmentation, and CNN-based recognition, complemented by a lightweight OCR module. The evaluation results show that the system works very well on important criteria, such as quickly identifying objects, being consistent across state forms, and having fewer false positives. Unlike IoT-centric models and complicated architectures like YOLOv10, the framework ensures processing in real time with the least amount of computing power needed, making it suitable for electronic roadways, automated tolling, and smart law enforcement use cases. Future enhancements will focus on edge construction, the integration of federate learning for confidentiality-preserving model updates, and the expansion of datasets to include multiple language

and nearby variants. This study improves LPR systems that are scalable, cheap, and reliable for Indian roads.

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