An ANPR-based Automatic Toll Tax Collection System using Camera

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Abstract—Several toll collection systems have been developed in India for highways, such as Manual toll collection, RF tags, Barcodes, and Number Plate Recognition. However, each system has its limitations, leading to errors and inefficiencies. This research provides a brief overview of current toll collection systems in India and their advantages and disadvantages. Additionally, it suggests the development of a new toll collection system that uses Computer Vision technology. The proposed Automated Toll Collection System will utilize unique identification numbers assigned to each vehicle in the form of number plates, storing basic information and the prepaid toll amount. Cameras will capture passing vehicles' images at the toll plaza, which will be processed using the Automatic Number-Plate Recognition algorithm. Once the vehicle passes the toll collection center, the system will deduct the toll amount from the prepaid balance, updating it accordingly. This proposed system aims to address the shortcomings of existing toll collection systems, offering a more efficient and cost-effective solution.

Keywords—Optical character recognition, Toll tax Collection, Number Plate Recognition, Edge detection, Automatic Number-Plate Recognition (ANPR), gaussian blur, morphological operations.

I. INTRODUCTION

With the growing number of vehicles serving as the primary mode of transportation, minimizing transportation problems and costs has become increasingly important. Toll systems have been developed to address these challenges, particularly at borders and toll gates, to automate the toll collection process. The toll system is designed to manage the flow of vehicles and reduce congestion on roads by determining whether a vehicle is registered under the government of the country and stopping it at the toll plaza [5][6]. The Number Plate Recognition system is a crucial part of this process, utilizing Optical Character Recognition (OCR) to convert the lettering on the number plate image into text that can be decoded later [7][8]. This enables tollway and parking authorities to manage the flow of vehicles by automatically detecting and reading number plates to provide a toll tax or enable vehicle parking in designated areas. Although current techniques and algorithms for vehicle quantity and number plate recognition have been extensively reviewed, there is a lack of commercially available Automatic Number-Plate Recognition (ANPR) gadgets that meet specific requirements. Therefore, a customized ANPR system is being developed in every industry. This system utilizes template matching on quantity plates acquired from static photos, with an approximate average accuracy rate of 90%, demonstrating the potential for accurately identifying and recognizing number plates with the proposed ANPR system. [9] To further improve accuracy and performance, artificial intelligence and machine learning algorithms could be

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employed to enhance the system's capabilities in identifying and matching number plates with the database.

II. RELATED WORKS

TABLE 1: Limitations of the existing methodologies

	Title	Techniques used	Limitations
1	An Automatic Number Plate Recognition System using OpenCV and Tesseract OCR Engine [Andrew S. Agbemenu, 2018]	Number Plate Recognition, Character Localization.	This system only captures the image of a vehicle once it has passed through, which does not help in reducing the queue line.
2	Review on optical character recognition [Muna Ahmed Awel, 2019]	OCR, handwriting character recognition.	It only discusses research on character recognition for English, Arabic, and Devanagari languages, which could limit its applicability for individuals interested in OCR technology for other languages.
3	Comparative Analysis on YOLO Object Detection with OpenCV [H. Deshpande, 2020]	YOLO, CNN.	Although it is mentions that YOLO has efficient object detection without compromising performance, it does not provide an evaluation of YOLO's performance in real-world situations or a comparison with other object detection techniques.
4	Automatic number plate recognition for different fonts and non-roman script [Chaitanya Ghangurde, 2020]	Segmentation, Character recognition.	It specifically focuses on the ANPR system for recognizing Indian number plates and does not discuss the implementation or effectiveness of the system in other countries.
5	Automatic Number Plate Recognition [Vanshika Rai, 2021]	OCR, ANPR.	The system could be improved by using deep learning-based algorithms for vehicle detection and number plate recognition, which could potentially improve accuracy and performance.
6	Electronic Toll Collection System Using ANPR [KVBL Deepthi, 2022]	OpenCV Raspberry pi 3, IR Sensor.	Artificial intelligence and machine learning algorithms can be used to make the system more efficient and accurate in identifying the vehicle number plates and matching them with the database.

The table above shows the work done on toll systems and ANPR technology.

Efficient traffic flow management and revenue generation in the transportation industry heavily depend on toll collection systems. While manual toll collection and barcodes are available, the RFID tag system is the most widely used. This system uses a unique tag attached to each vehicle containing vital information such as user and vehicle data, making it user-friendly with automated payment deduction and multiple toll booth usage. However, RFID tags require periodic maintenance, risk fraud, and have drawbacks such as long queues and high costs during peak hours, which can lead to productivity loss and inconvenience for commuters. Therefore, evaluating the pros and cons of each toll collection system and exploring alternative options, especially for small transportation companies, is essential to ensure an effective and streamlined transportation system while weighing potential RFID disadvantages such as fraud and privacy breaches.

III. PROPOSED FRAMEWORK

The proposed approach involves utilizing a camera at the toll booth to obtain a picture of a vehicle's number plate. Afterward, an ANPR algorithm is employed to extract the number plate characters from the image, which are then compared to the database of registered

vehicles [10]. In the case of a registered vehicle, the toll fee is automatically deducted from the user's account, and the gate is opened automatically, allowing the vehicle to pass through. However, if the vehicle is not registered, the system notifies the user to pay the toll manually.

The proposed toll tax collection system aims to revolutionize the way tolls are collected by providing an efficient and automated system that reduces the time taken for toll collection. This system relies on digital toll collection, eliminating the need for physical toll booths and manual collection of toll fees. The system leverages the existing infrastructure of toll plazas, which are already equipped with cameras. The camera captures a video of the vehicle as it enters the toll gate, and the ANPR algorithm processes the video to extract the number plate [11]. The extracted number plate is then compared with the authorized plate number in the system's database. The toll system is connected to the database to enable OCR to verify the registered data and deduct the tax from the user's prepaid wallet. The proposed system has the potential to make toll collection more efficient and reduce the traffic congestion at toll plazas.

IV. REVOLUTIONIZING TOLL COLLECTION

The proposed toll tax collection system is an automated and accurate digital toll collection system that offers several advantages over traditional toll tax collection systems. This system minimizes errors in toll collection and reduces the need for human intervention, making it ideal for busy toll plazas where there are long queues. The system also has a low maintenance cost as it does not require any physical tags or devices, making it a cost-effective solution [12]. Additionally, the OpenCV ANPR system offers enhanced security by detecting fraudulent number plates and providing real-time data of the number of vehicles passing through the toll plaza, which can be used for various purposes. Overall, this system offers high accuracy, elimination of long queues at toll plazas, automation, cost-effectiveness, enhanced security, and real-time data.

V. METHODOLOGY

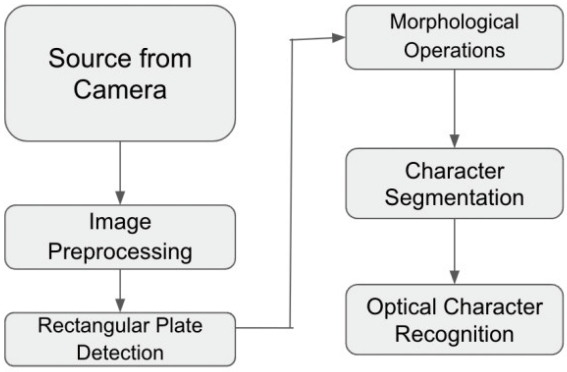

Fig. 1. Methodology of the System

A. Image Preprocessing

Image preprocessing is an essential step to ensure the accuracy of license plate detection and character recognition using ANPR technology [13]. The following steps are generally performed as part of the image preprocessing phase:

- **Grayscale Conversion:** The input image is first converted from its original RGB color space to grayscale [14]. This helps in simplifying the image by reducing the color information, which in turn reduces the computational complexity of further processing.
- **Noise Reduction:** ANPR systems are susceptible to noise present in the input images. Hence, various noise reduction techniques such as Median filtering and Gaussian filtering are applied to reduce the noise present in the input image. This is done to enhance the license plate's edges and make it more visible [15].
- **Image Enhancement:** The contrast of the input image is enhanced to make the license plate's edges more visible. This is achieved by applying Histogram Equalization and Contrast Limited Adaptive Histogram Equalization (CLAHE) techniques.
- **Morphological Transformations:** Morphological transformations like dilation and erosion are applied to the preprocessed image to enhance the edges of the license plate regions [16].

- **Binarization:** After enhancing the edges, the image is binarized, which means that it is converted into a binary image. This is done to separate the foreground (license plate region) from the background [17].

These preprocessing steps help in improving the image quality and reducing noise, thereby increasing the accuracy of the license plate detection and character recognition.

B. CVTColor

The cvtColor function is a versatile tool that enables the conversion of images between various color spaces, making it a crucial step in many image processing tasks, including ANPR [18]. The selection of a color space is dependent on the specific needs of the application and the image processing steps that follow the color space conversion.

C. Gaussian Blur

The Gaussian blur technique is a beneficial feature of OpenCV ANPR that helps to reduce noise and smoothen images, resulting in better accuracy and reliability of subsequent image processing steps like edge detection and character segmentation. It is frequently used as a preliminary step in ANPR systems to enhance their accuracy and efficiency.

D. Rectangular Plate Detection

In this system, rectangular plate detection plays a vital role in identifying and localizing the license plate region in an input image. This region is rectangular and includes the license plate characters, making it the focus of subsequent image processing steps like character segmentation and recognition. The sliding window approach is a commonly used technique in OpenCV ANPR for rectangular plate detection [19]. This method involves moving a fixed-sized rectangular window over the input image, and a classifier is used to determine whether the current window contains a license plate or not.

E. Sobel

Sobel is a popular edge detection technique used to identify edges in an image. The Sobel function in OpenCV takes two parameters and the output of the Sobel operator is a gradient magnitude image, which represents the strength of edges in the input image [20].

F. Character Segmentation

It involves separating each character present on a number plate image to avoid errors in character recognition. This process is challenging due to variations in character size, font, and orientation. Techniques such as thresholding, morphological operations, and contour analysis are used to achieve accurate character extraction. The denoised characters are then arranged in a single line, ready for recognition. Overall, character segmentation is a critical component of the ANPR system, ensuring the precise recognition of alphanumeric characters on a number plate.

G. Morphological Operations

Morphological operations are utilized in character segmentation to remove noise, smooth edges, and fill gaps or holes in characters. Dilation is used to expand characters, while erosion separates characters from each other and the surrounding background. Opening removes small objects within characters and closing fills gaps or holes in characters. Morphological operations are helpful in handling variations in character size, font, and orientation, improving the accuracy and reliability of character recognition.

H. Optical Character Recognition

OCR is essential to recognize the alphanumeric characters present on the detected number plate. To achieve high accuracy in the recognition process, the widely used Tesseract OCR engine is trained using various techniques. One such technique involves creating images of the characters using expected fonts, and compiling a dictionary of possible character combinations that can be present on a number plate. This dictionary contains regional codes, suffixes, and registration numbers. By utilizing these methods, the OCR stage can accurately convert the detected number plate into its textual representation, which represents the vehicle number. This ensures a more reliable and efficient vehicle detection process, providing various benefits, including reducing traffic congestion and facilitating toll collection.

VI. RESULTS AND DISCUSSION

The effectiveness and efficiency of the proposed system for toll collection have been tested in a real-time environment, and the results indicate a high level of accuracy. The waiting time at the toll booth has been notably reduced, providing a faster and more efficient method for collecting tolls. Additionally, the system can be seamlessly integrated with other payment systems, such as e-wallets and credit cards. The proposed digital toll collection system comes with a user-friendly application that allows users to create an account and add funds to their wallet for paying toll taxes. The wallet balance can be used to pay for toll taxes at toll booths, and users can check their balance within the application.

The ANPR algorithm processes the captured image of a vehicle's number plate to extract the number plate when it enters a toll booth. The extracted number plate is then matched with the authorized plate number stored in the system's database. If the number plate is authorized and the user's wallet balance is sufficient, the toll tax is automatically deducted from their wallet. If the user's wallet balance is insufficient or the account does not exist, an error message is displayed, ensuring that only authorized users pay taxes. The mobile application offers additional features, such as account management and transaction history, allowing users to monitor their toll tax payments and wallet balance.

Furthermore, the system provides real-time data on the number of vehicles passing through the toll plaza, which can be used for traffic analysis and planning. Overall, the proposed digital toll collection system offers a secure, convenient, and efficient way for users to pay toll taxes while providing real-time data for toll plaza management.

Fig. 2. Home page of the application

Fig. 3. User signup page

Fig. 4. Sign-in page for the user

Fig. 5. User's Recharge page

Fig. 6. User's balance in the wallet

Fig. 7. Admin login page

Fig. 8. The amount is successfully deducted from the user's wallet

Fig. 9. Payments details of the vehicles

Fig. 10. Error for non-existing user or insufficient funds

VII. CONCLUSION & FUTURE SCOPE

This system offers a dependable and effective method of toll collection. Implementing the Automatic Number-Plate Recognition (ANPR) algorithm has minimized the waiting time at the toll booth, resulting in a faster and more efficient toll collection process. The system is user-friendly and easily integrable with other payment systems. It can be applied to various settings, including toll booths, parking lots, and other locations where automatic payment collection is necessary. The Automatic Toll Collection System with ANPR camera is an efficient and dependable way to collect tolls without human intervention. It eliminates the possibility of human errors, thus improving accuracy. It also reduces wait times for drivers and toll collectors, saving time for both parties. This system utilizes advanced image processing techniques to precisely identify license plate numbers and collect tolls without any physical assistance. It is a cost-effective and scalable solution that can be integrated seamlessly into existing toll collection infrastructure. The future of this system looks promising with possibilities of improving accuracy and speed through continued research and development. The integration of machine learning algorithms can enhance the system's ability to recognize license plates even in different lighting and weather conditions. Overall, the Automatic Toll Collection System using ANPR is a technology with vast potential to simplify toll collection processes and enhance the overall transportation experience for drivers. As technology progresses, ANPR systems are expected to become even more efficient and effective, making them an essential part of modern transportation infrastructure.

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