Automatic Toll Collection using Vehicle Number Recognition System

Dr. P. Sai Kiran
Professor, Department of Computer Science and Engineering, Prasad V Potluri Siddhartha Institute of Technology, Vijayawada-520007, India.
email: psaikiran@gmail.com

Yalanati Ayyappa
Assistant Professor, Department of Computer Science and Engineering, Prasad V Potluri Siddhartha Institute of Technology, Vijayawada-520007, India.
email: ayyappa9866@gmail.com

Maddila Kavya sree
Student, Department of Computer Science and Engineering, Prasad V Potluri Siddhartha Institute of Technology, Vijayawada-520007, India.
email: kavyamaddila2202@gmail.com

Jaswanth Jampani
Student, Department of Computer Science and Engineering, Prasad V Potluri Siddhartha Institute of Technology, Vijayawada-520007, India.
email: jaswanthjampani217@gmail.com

Mounisha Raavi
Student, Department of Computer Science and Engineering, Prasad V Potluri Siddhartha Institute of Technology, Vijayawada-520007, India.
email: raavimounisha5@gmail.com

Karthik Aluru
Student, Department of Computer Science and Engineering, Prasad V Potluri Siddhartha Institute of Technology, Vijayawada-520007, India.
email: alurukarthik5@gmail.com

***Abstract*— With an increasing number of on-road vehicles, there is an increasing need to save time for drivers and travelers without waiting in long lines or stop at every toll booth. This research study intends to develop an upgraded FasTag system, which eliminates the need for toll booths. The proposed automated toll collection system is developed by using vehicle number recognition, which reads vehicle license plates from images using OpenCV and Tesseract OCR Engine. This can be accomplished via human agents or highly advanced smart technology that recognizes automobiles in real-time environment based on the license plates. The proposed technology detects number plates, identifies the vehicle based on the license plate number, and then sends the appropriate toll amount as an SMS to the car owner for payment purpose.**

Keywords—Toll collection, Number plate recognition, OpenCV (Computer Vision), TesseractOCR (Optical Character Recognition) Engine

I. Introduction

Automatic Number Plate Recognition (ANPR) is a technology that reads vehicle numbers using pattern recognition. ANPR cameras 'photograph' the license plates of the cars that pass them, to put it simply. The information from this "picture" is then entered into a computer system to learn more about the vehicle. A computer and cameras are used in ANPR. When a vehicle passes, ANPR "reads" the vehicle registration marks or number plates as they are more popularly known from the digital images taken by cameras that are either built into traffic vehicles, mobile units, or closed-circuit television (CCTV). The digital image is transformed into data and put via the ANPR system for processing. Locating rectangles in a vehicle image using edge detection, OCR, and other techniques was the major method we offered. Having a car today is no longer just a sign of luxury; it is now a need. But when it comes to motor vehicles, anything bad can happen. Hence, it is always vital to put in place the necessary arrangements to boost safety and security as well as to monitor the vehicles to prevent any accidents. We could use it in the following circumstances: Get car information right away using picture processing. enabling a company to find where its vehicles are. All traffic infractions associated with the car should be automatically reported to the user. Using a GPS-based vehicle tracking system is one such safeguard (Global Position System). In addition to the text from the license plate and the images captured by the cameras, ANPR systems may be set up to save a photograph of the driver. Systems frequently employ infrared illumination to enable the camera to take the picture at any time of day. At least one variant of the junction monitoring cameras has a strong flash that both illuminates the scene and alerts the violator to their error. Because to regional variances in plate patterns, ANPR technology is usually region-specific. Digital picture acquisition frequently experiences unfavorable camera shaking and unpredictable, erratic camera motions. Algorithms for picture improvement are therefore needed to eliminate these undesirable camera tremors. The primary programming language is Python.

The following are some benefits of the present work over the FasTag system:

1. The ATCS (Automatic Toll Collection system) uses Tesseract and OCR technology, whereas the FasTag system uses RFID technology.
2. In ATCS systems, toll amounts are immediately deducted through the cameras without stopping at toll booths, as opposed to scanners at toll booths in FasTag systems.
3. Toll booths must be stationed in the systems equipped with RFID technology, however ATCS totally does away with toll booths. Moreover, extended line wait times can be minimized.

A. OpenCV

For computer vision in artificial intelligence, machine learning, facial recognition, etc., OpenCV is a Python open-source library.

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The term Computer Vision (CV) in OpenCV refers to a branch of research that enables computers to comprehend the content of digital images like images and movies.

To comprehend the content of the images is the goal of computer vision. It takes the description of the images—which may be of an object, a text description, a three-dimensional model, etc.—and extracts it from the images. Computer vision, for instance, can help cars by enabling them to recognize various roadside items, such as pedestrians, traffic signs, and traffic lights, and then respond appropriately. Around 14 million downloads and an estimated 47 thousand users make up OpenCV's user base. Businesses, research teams, and governmental organizations all use the library extensively. Several startups, including Applied Minds, VideoSurf, and Zeitera, heavily rely on OpenCV in addition to well-known corporations using it, like Google, Yahoo, Microsoft, Intel, IBM, Sony, Honda, and Toyota. Street view image stitching, monitoring mining equipment, helping Willow Garage robots navigate and pick up objects, identifying drowning incidents in European swimming pools, running interactive art in Spain and New York, looking for debris on Turkish runways, checking product labels in factories around the world, and quick face detection are just a few applications for OpenCV.

It supports Windows, Linux, Android, and Mac OS and provides C++, Python, Java, and MATLAB interfaces. When they are available, MMX and SSE instructions are used by OpenCV, which strongly prefers real-time vision applications. Complete CUDA and OpenCL interfaces are now under active development. There are over 500 algorithms, and each algorithm depends on about ten times as many functions. OpenCV's templated interface, which was created entirely in C++, works well with STL containers. Both academic and commercial use of OpenCV is free because it is released under a BSD license. It has C++, Python, and Java interfaces and supports Windows, Linux, Mac OS, iOS, and Android. Real-time applications were heavily emphasized when OpenCV was developed. Because the library was created using effective C/C++, It could benefit from multi-core processing. When OpenCL is enabled, it can profit from the underlying heterogeneous compute platform's hardware acceleration. OpenCV has become widely used, with over 47,000 active users and an estimated 14 million downloads. Uses include cutting-edge robotics, interactive art, mine inspection, and online map stitching.

B. Py-Tesseract

Py-Tesseract is a tool for optical character recognition (OCR) in Python. To put it another way, it will recognize and "read" any text that appears in images. Python-tesseract is used to encase Google's Tesseract-OCR Engine. As a result of its ability to read all image formats, including jpeg, png, gif, bmp, and tiff, it is also utilized as a standalone script. In addition, Python-tesseract will output the recognized text when used as a script rather than storing it to a file. It can recognize more than 100 different languages.

C. GSM (Global System for Mobile)

The Global System of Mobile Communications, or GSM. GSM is a cellular open, digital technology used for mobile communication. It operates in the 850 MHz, 900 MHz, 1800 MHz, and 1900 MHz frequency bands, respectively. It combines the use of FDMA and TDMA. In GSM, there are four different cell sizes: This size of cell houses the base station antenna. Micro: In a cell of this size, the antenna height is below the average roof line. Pico: Little cells have a diameter of a few meters. fills up the spaces between the cells to cover the shadowed areas. In order to monitor wireless radiation, the GSM module that powers the Short Messaging Service (SMS) has been changed. This module may send text SMS data to a host server after receiving bit stream from radioactive monitoring devices like survey meters and area monitors. For the transfer of data, status inquiries, and configuration setup, it offers two-way communication. An Atmega328P CPU, a voltage level shifter, a SIM circuit, and a GSM module make up the hardware of the module as shown in Fig. 1.

Atmega328p microcontroller is used because of its benefits such as low-powered and low-cost. Since it is small and affordable, making it an excellent choice for various applications and in our project as well.

When an AT command is sent, received, or processed, the microcontroller controls the GSM module. Tasks involving communication between the host server and the device are managed by the firmware. All incoming SMS are processed, new configuration is taken from the host and saved, alert/notification SMS are sent when radiation data exceeds threshold values, and message data are transmitted at setup-specified intervals. By combining this module with a radiation survey/monitoring system at high-level radiation structures like LSTM, BLSTM, and Bi-GRU, a portable and wireless radiation monitoring system with an immediate urgency alarm will be produced. Target labels are projected using RNN structures and a CTC cost function from expected sequences.

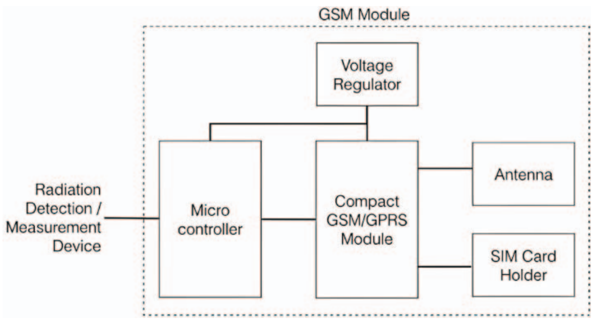


Fig. 1 Block sketch of GSM PCB Module

II. LITERATURE REVIEW

A. VEHICLE LICENSE PLATE DETECTION USING IMAGE PROCESSING

We will be utilizing CCTV video or provided input photographs in this technique.[3] For the vehicle number to be extracted from the image used as input, the CCTV footage must be clear.[3] These input photos are made grayscale, and OCR is used to segment and identify the characters. For this software to operate, several requirements must be met:
1) Automobile license plates must be white and adhere to the regulations set forth by the Indian government.
2) The brightness and contrast of the image should be adequate. In this, a software is created that uses MATLAB to detect the car license plate number.

In order to find the car number, we will use a variety of different ways in this methodology. Then, we'll compare that number from our database using the discovered car number.

B. Number Plate Recognition Using Support Vector Machine (SVM)

ANPR is a form of widespread monitoring that takes pictures of moving objects and reads their license plates. Using SVM, a system is proposed in this research that successfully locates and reads Indian license plates from digital photos. Pre-processing and number plate localization are carried out in this suggested model utilizing, respectively, feature-based and Otsu's approaches. It delivers dependability and time optimization.[1] The character reorganization is completed using the Support Vector Machine. Another algorithm for number recognition is suggested in this work. In this method, character samples are trained using a Support Vector Machine (SVM) to generate the rules needed to identify the numbers on license plates. SVM is a method for pattern classification that is fiercely competing with many others. A supervised learning method called an SVM was first introduced by Vatnik. In order to get the best generalization, SVM uses the Statistical Learning Theory (SLT) as its theoretical basis and structural risk minimization as its ideal object. They offer a clear intuition of what learning through examples is all about and are founded on a few basic notions. They have the quality of excellent performance in real-world applications, which is more significant. SVMs have risen to prominence in the aspect of pattern recognitions over the years, starting in the 1960s and continuing to the present.

C. Auto Digits and Alphabets Recognition Based Online Toll Collection System

Automatic highway toll collection systems based on radio frequency identification (RFID) are very common in developed nations. Yet, because to its high cost, developing nations cannot afford to integrate RFID into every vehicle. Also, because metal items can affect Radio Frequency (RF) fields, being too close to any metal object when reading RFID data may produce undesired noise.[5] These issues continue to be grave worries. To solve these problems, we suggest a more effective, dependable, and affordable automated toll collection system based on vehicle number plate recognition.[11] The Normalized Cross-Correlation (NCC) based template matching technique is used in this study to recognize the characters from each vehicle's license plate. A fixed amount of toll is automatically levied after successfully deciphering characters from a number plate in accordance with the type of the vehicle.

D. Auto License Number Plate Recognition System using Four Deep Learning Networks

The technology and services focused towards intelligent transportation networks and smart cars are still transforming many facets of daily life. This is an established part of our culture.[4] Automatic License Plate Recognition (ALPR) is the process used to look up a car's license plate in a collection of images or videos (ANPR). An further benefit of ANPR technology is that it lessens the need for human involvement, which enables Intelligent Transportation Systems. The main aim of this project is to determine the optimum algorithm for license plate recognition. The research makes use of four deep neural networks, including CNN, VGG16, VGG19, and YOLOV3, to identify the license plate and assess the models' performance in aspects of accuracy and find out the best model.

E. An Efficient Toll Bill System using Deep Learning

Customers who are waiting in long lines to enter can become frustrated by the fruitless process at the toll gates. What if the process was quick and human involvement was tapered off at the toll gates?[8] The purpose of the exposition is to address the aforementioned issues and help the business implement a completely automated toll billing system. Artificial intelligence integration into the toll collection system may ease the tedious procedure and offer a hassle-free toll deduction experience.[10] With this project, we reward those who complete their tasks more quickly and pass through the toll gate first. The project will contribute to the automation of the toll gates and offer a new user experience.

III. Problem Statement

The number plate of the vehicle is used to identify it by an image processing method called Automated Number Plate Recognition (ANPR). The objective is to develop an effective license plate-based automatic approved vehicle identification system. The created system first recognizes the car before taking a picture of it. The region of a picture containing the engine number plate is retrieved using image segmentation. An optical character recognition method is used for character recognition. There have been several new technological developments in recent years. These technological developments could lead to a number of major problems for people. Some of the unfavorable consequences connected with the discovery of such issues can be mitigated by employing a number of tactics. This can be done using human agents or sophisticated intelligent technology that recognizes automobiles in real surroundings based on their license plates.[7] The car number plate detection and identification system is employed to find the plates, identify the plates, and obtain the text from an image. It makes use of character recognition, segmentation of characters and GPS algorithms. The system of detecting and recognizing vehicle number plates is one example of intelligent equipment.

The program's goal is to identify and continue following a specific object of interest (in this case, a car) in video frames. The project's two main drivers are the shocking financial and human cost of car accidents, as well as the difficulty of accurately identifying automobiles in photographs taken from moving platforms. In this study, Computer vision techniques with OpenCV, character recognition with Convolution Neural Networks, and vehicle detection and deep learning methodologies are merged.[9]

Automated number plate recognition employs Pytesseract, an effective OCR engine, together with significant and extensive OpenCV libraries for image processing. As we have shown, the majority of the issues we have raised can be solved with ANPR. Now that we've dug a little deeper, we want to emphasize the project's scale and the limits we can push. We can assert that utilizing our technology, we can implement it in any situations, whether it rain or shine. The biggest problem that is commonly identified when it comes to number plate detection is the noise that is introduced to the image during the process of acquiring the image or due to the environment around. The incorporation of new features into their current system is typically the main concern of potential clients when any new system is suggested. Considering this, we are certain that our system can be added to the pre-existing infrastructure of the majority of clients.

IV. Suggested Methodology

The goal of this research is to create fresh methods for extracting license plates. The proposed algorithm is based on video acquisition, plate region extraction, segmentation of plate characters, character recognition, and SMS sending using GSM as in Fig. 2. Plate extraction is a challenging task. This project presents a straight forward license plate extraction technique. The process consists of four basic processes, including the conversion of RGB photos to grayscale, Gaussian blurring, morphological techniques, and precisely retrieving the location of the license plate. It is dependent mostly on the Edge Detection algorithm. The mean squared error approach is employed for character recognition. The license plate number is checked in our database after extraction. The owner of the car is then issued an SMS with information on the toll.

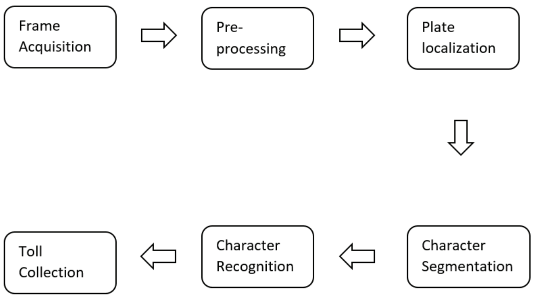


Fig. 2 Methodology

A. *Pre-processing*

Pre-processing steps involves the following methods:

1. Gaussian Blur : Gaussian noise in the image can be effectively eliminated by gaussian blurring. An image blur is created by a low-pass filter kernel confusing the image. It really blurs the borders of the image by removing high frequency material (such as noise and edges) from it. This method substitutes a Gaussian kernel for a box filter made up of equal filter coefficients. The cv2.GaussianBlur function is used to accomplish that.

2. Gray scale conversion : It entails converting an RGB image to a grayscale image. A gray-scale image is made up of several grey color tones. By keeping the image's luminance (brightness), a true color image can be turned into a grayscale image. The RGB image displayed here is made up of the colors RED, BLUE, AND GREEN. The RGB image is converted to a grayscale image by adding 30% RED, 60% GREEN, and 11% BLUE. This discloses the image's brightness information. It will produce a two-dimensional image. Black is represented by the value 0 and white by the value 255. Black and white values will make up the range.

3. Sobel operator : It is utilized in computer vision and image processing, especially in edge detection techniques where it produces an image that emphasizes edges. Gradient-based techniques are used in the Sobel edge detector. First order derivatives are compatible with it. It calculates the image's first derivatives for the X and Y axes individually. The derivatives are merely estimates (because the images are not continuous).

4. Thresholding : Converts a grayscale image to a binary image. A pixel receives one value (perhaps white) if its value reaches a threshold value; otherwise, it is given a different value (may be black). Cv2.threshold is the function that is utilized in this process. The source image, which must be a grayscale image, is the first argument for this function.

B. *Plate Localization*

Plate localization is based on morphological operations and aspect ratio.

i) Morphological operation:

There could be several flaws in binary images. For instance, noise and texture modify the binary zones created by straightforward thresholding. By considering the geometry and structure of the image, morphological image processing aims to address these problems. These techniques can be used to alter grayscale images. In morphological techniques, the concept of a structuring element refers to a little form or template that is utilized to investigate a picture. Every possible location within the image is used to position the structuring element, which is then contrasted with the pixel neighborhood that corresponds to that location. While other operations check to see if the element "hits" or intersects the neighborhood, other operations check to see if the element "fits" within the neighborhood. When performing morphological operations on binary images, the resultant binary image only contains pixels with non-zero values when the test at that place in the input image is successful. Each pixel of a bounding box that is added to a source images is connected to the corresponding pixel of the neighborhood that sits beneath the bounding box. For the image to be considered to fit, every pixel in the structural component and its corresponding pixel in the output image must both be set to 1. If at least one of a structuring element's pixels is set to 1, and the matching pixel in the image is also 1, then the structuring element also "hits" or "intersects" the image.

ii) Localization:

The candidate for the license plate is chosen focused on the aspect ratio of the contours.

iii) Character Segmentation:

To segment individual characters in the license plate.

This is the most critical phase in OCR since it is the key factor for boosting the accuracy of OCR system. Character segmentation that is done well will result in high recognition accuracy. Fig. 2

iv) Character Recognition:

A database of templates or characters is used in this process. For each potential input character, there is a template. For each of the alphanumeric characters, templates are made (from A-Z and 0-9). For picture similarity, the mean squared error approach is employed. Each segmented character from the license plate is compared to every character in the standard template, and any discrepancies are noted. The template with the lowest error value is regarded as matching the character.

C. *Toll Collection*

After recognizing the vehicle license plate, the license number is sent to the database so that the phone number is extracted from the corresponding owner details and then the message is issued to the user's mobile number using GSM as the money has to be paid.

The database is used to store the registered number plates and then compare if it is valid number plate or not and the database contains the attributes Name, License Number, Phone number, Location, Toll fee. We are retrieving the Required details from the database and then sending an SMS.

V. Experimental Design and Outcomes

The Experiment is conducted based on the below system requirements

- RAM: 4GB or more
- Intel i3 CPU or higher
- Python software

Several license plates with varying backgrounds, lighting, and video quality were used to test the system. Understanding the terms true-positive, false-positive, and false-negative is necessary for calculating the precision and recall values. The entirety of the output file's "recognized" text, whether correctly or incorrectly recognized, serves as confirmation for the affirmative class. The items that are rightly rejected are those that are true-negative. (For example, in 53-NP-RR, hyphens are correctly discarded as non-characters, resulting in 53NPRR as the output.) Both the ground truth file and the program's output file will contain those characters. False-positives are things that are mistakenly classified as being in the positive category; in this case, they are all the wrongly identified characters. Items that should have been classified as positive but weren't are called false-negatives. The characters in the ground truth file that are absent from the program's output file are considered false-negatives in this situation since they were there in the image but were not recognized.

Precision is the percentage of correctly classified instances or samples among those categorized as positives. As a result, the precision formula is as follows:

$$Precision = \frac{True\ positives}{True\ positives + False\ positives}$$

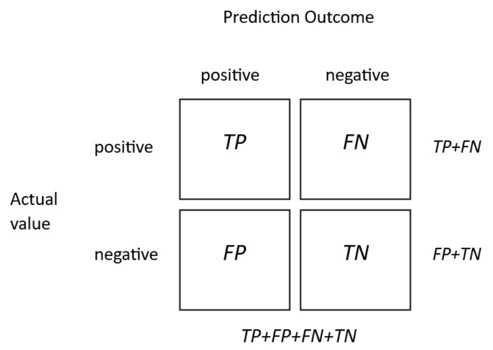
The recall is determined as the proportion of Positive samples that were correctly identified as Positive to all Positive samples. The recall gauges how well the model can identify positive samples. The more positive samples that are identified, the larger the recall.

$$Recall = \frac{True\ positives}{True\ positives + False\ negatives}$$

The frequency with which the model predicts the right result is known as accuracy. It can be measured as the proportion of the classifier's right predictions to all of its other guesses. The formula is provided below.

$$Accuracy = \frac{True\ positives + True\ negatives}{True\ positives + True\ negatives + False\ positives + False\ negatives}$$

Prediction Outcome of the work:



A. Results

Actual plate	Predicted plate	Precision	Recall	Accuracy
53-NP-RR	53NPRR	6/(6+0) = 100%	6/(6+0) = 100%	(6+2)/(6+2+0+0) = 100%
63-LD-LG	63LDLG	6/(6+0) = 100%	6/(6+0) = 100%	(6+2)/(6+2+0+0) = 100%
JGH 5337	JGH5337	7/(7+0) = 100%	7/(7+0) = 100%	(7+0)/(7+0+0+0) = 100%
JGG2373	GG2373	6/(6+0) = 100%	6/(6+1)=85.71%	(6+0)/(6+0+0+1) = 85.71%
Average		100%	96.42%	96.42%

Table 1. Results

B. Predictive Error Metrics for proposed methodology and existing

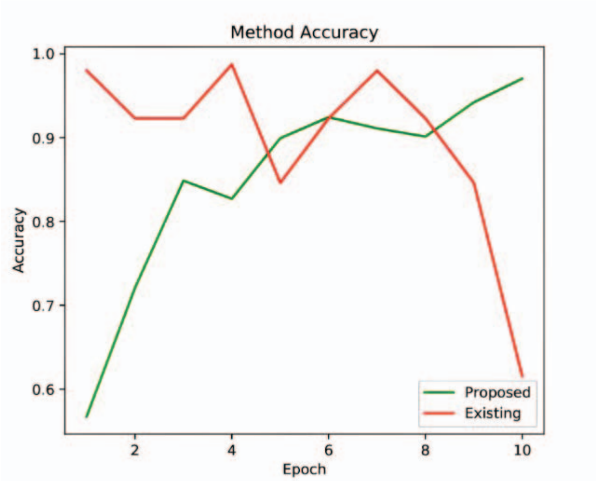


Fig. 3 Prediction Accuracy metrics

VI. Conclusion

The automotive, two-wheeler, and auto industries in India are expanding incredibly quick, making ALPR applications more difficult to use. Applications of ALPR, such as automatic toll collection, parking spot charging systems, management cars, traffic monitoring, etc., have created new research challenges with fresher dimensions. By using data from a live video feed, we have created software for automatic license plate recognition. For the retrieved license plates, character segmentation has been used. The mean squared error approach is used to identify the segmented characters. Lastly, creating the toll bill and sending the car owner an SMS.

This work can be even more extended with an application where the car vehicle registration can be done and can view the travel summary of the vehicle. This project can also be improved with the accuracy by using YOLOv3 to v8 algorithms and easyOCR technique for recognition.

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