Vehicle License Plate Recognition for Mobile Road Policing

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ABSTRACT
Automatic vehicle license plate recognition and identification has many applications in intelligent traffic management systems. License plate recognition is an effective form of vehicle identification for traffic police. In this paper, we describe a novel application designed for vehicle license plate recognition using a mobile phone camera. We use the state of the art image processing and pattern recognition algorithms tuned for Indian conditions to automatically recognizing the characters on the license plate images. The client-server architecture consists of a client application running on a mobile device and a centrally hosted server application with access to vehicle information database. The vehicle plate image captured by the mobile phone along with the location information is passed to the server where the license number is recognized and makes available all the details pertaining to the vehicle to the client for instantaneous viewing. The end to end system architecture is described in detail including data (license plate images) capturing, image pre-processing, number plate localization, character segmentation, character recognition. The vehicle identification based on the recognized registration number and the location information with the help of external databases is also integrated to the system. A working prototype of the proposed system has been developed in the lab environment.

1. INTRODUCTION
Automatic license plate recognition systems are usually designed to automatically recognize and store license plate number data on vehicles passing through a certain point. At present, systems are available for mass surveillance that utilizes optical character recognition (OCR) programs and hardware capable of reading license plates of moving vehicles. Some systems make use of infrared cameras to increase the efficiency of the system. These systems can be used for traffic monitoring, enforcement, collect electronic tolls, etc [2] [3] [4] [8] [9]. In all these systems the camera is fixed and hence is only able to scan the vehicle passing through a particular point. On the other hand an automated, mobile license plate recognition system has become an essential necessity for traffic control and law enforcement especially with increasing volumes of traffic being added to Indian roads every year. Traffic police not only make sure that the motor vehicles on the road follow the basic traffic rules but also make sure that the vehicle has necessary authorizations to be on the road. In any large city the traffic police can police a fraction of the city and when ascertaining for details have to rely on the details provided by the vehicle driver. In this paper we address the problem of assisting the traffic police being aware of the exact details of a vehicle on the road 24x7. We propose a mobile phone based vehicle number plate recognition system to assist the traffic police. Additionally, the system enables the police to issue memo for the breach of provisions of motor vehicle act and rules.

The core unit of the proposed architecture is the automatic license plate recognition from the images captured through the mobile phone. We use the format of the number plate (based on modern Arabic numerals with Roman alphabet) with unique codes used for Indian states and Districts to make the license plate recognition system robust. The number plate image is assumed to be captured from a distance of less than 4 meters using a mobile phone camera when the vehicle is stationary. It should be observed that several factors affect the quality of the captured image thereby degrading the performance of the character recognition engine. To name a few, (a) low quality image may occur due to poor resolution of the camera, (b) image being captured from far, poor lighting etc. (c) image distortion due to shadows that partially cover the license plate blurry images, due to, vehicle in motion; (d) atypical font used for number plate (italics and writing of numerals in the local script etc.) are other important issues a vehicle number plate recognizer has to deal with. The focus of our work is to build a prototype vehicle number plate recognizer in client-server architecture. In Section 2, we describe the overall system architecture that is developed and tested in the laboratory environment including the sub-modules.

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Experimental results are discussion of the Section 3. Conclusions and descriptions on the potential application areas, where we can deploy the system, are explained in Section 4.

2. THE SYSTEM ARCHITECTURE

The system is based on client-server architecture. Figure 1 shows the high-level solution architecture. The functional modules on the client and the server are described in Section 2.1 and 2.2.

Figure 1. The high-level architecture of the application

2.1 Client Functionalities

The major client components include (a) a server interface module and (b) a location identification module. The client application can be downloaded over the air (current implementation is on BREW but can be enabled for multiple mobile devices and multiple OS). The client includes a media interface (capture image) and a prompts menu, in addition it has the flexibility to be configured to work in the language of the user (any of the Indian languages). The client module communicates with the server using the HTTP.

The client application requests the user (using either a text message) to capture the image of the vehicle number plate (either the front or the back license plate of the vehicle) followed by enabling the camera capture mode on the mobile phone. When saved, the image is pushed to the server for recognition. Additionally the client software shows the relevant information (obtained from the server in response to the captured image) about the vehicle either as a text message in the chosen language to the end users. Figure 2 shows the client side solution architectures in detail.

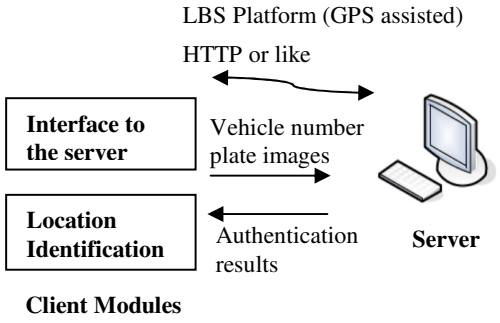


Figure 2. Solution Architecture in greater detail (Client side)

Another important module on the client is the location identification module. This module helps to locate the location of the mobile device. This module is designed as a Location Based Services (LBS) platform based on Global Positioning System (GPS). The location information captured here is sent to the server along with the image of the vehicle number plate. The location information captured along with the number plate information of the vehicle present at a specific location helps in vehicle tracking [4].

2.2 Server Functionalities

The major components on the server include (a) image processing and pattern recognition modules for recognizing number plate, (b) database interface. A regional language interface module is also present in the server end which provides the vehicle information, ownership details or complaint registration feedback in regional languages to the end user. Figure 3 shows the server side solution architecture in greater detail.

The server can interact with external databases and find the association between registration number and ownership details (name, contact address, number), vehicle details (make, model, engine number etc.), tax details and previous complaints registered against the vehicle. This collective information can be used with better effect by the traffic police especially under suspicious situations.

The server works on the image sent by the client while maintaining a link between the images uploaded and the mobile device through a unique session number. A module to recognize vehicle registration number from the image is designed here. Section 2.3 describes the functionalities of the number plate recognition engine in detail.

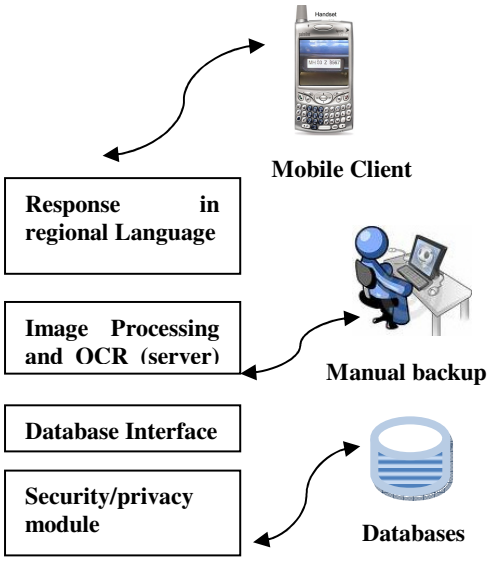


Figure 3. Solution Architecture in greater detail (Server side)

2.3 Number Plate Recognition Engine

The number plate recognition engine resides on the server and has various image processing and pattern recognition modules. The important functional units include image pre-processing, number plate localization, character segmentation and character recognition [1][5]. Figure 4 shows the block diagram of the number plate recognition engine.

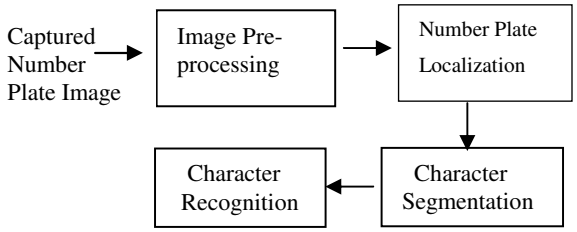


Figure 4. Block diagram of the proposed recognition engine

Sample images of vehicle number plates captured by mobile phone cameras are shown in Figure 5. It can be observed that the input images have a great deal of variability and the recognition system needs to account for this. The image pre-processing algorithms address these variabilities before the actual recognition is carried out.

2.3.1 Image pre-processing

The color image captured from the camera is first converted into a gray scale image and then is binarized using Otsu's global thresholding technique [7]. We can also use an adaptive threshold technique to get better binary image as the binarized edge map is used in the subsequent stages. Skew correction up to about +/- 5 degrees and slant normalization are the other two image pre-processing techniques used before number plate localization is carried out.

Figure 5. Images of the number plates taken using mobile phone cameras

2.3.2 Number Plate Localization

The localization of the number plate region is the next step on the pre-processed image. Determining the location of the number plate within the captured image automatically is a critical task for successful recognition. The aim is to obtain a region of interest (usually a rectangular window) in the test image that includes the license plate of the vehicle. For this purpose, the edge map $E(x,y)$ of the input image $I(x,y)$ of size MxN is initially computed by applying the Sobel edge operator. The edge magnitude is the combination of edge strengths along the horizontal and vertical directions and is given by

$$E(x,y)=\sqrt{E_h^2(x,y)+E_y^2(x,y)}$$

Stray edges are removed by low pass filtering the edge map. A coarse search for the number plate region is carried out using edge density feature computed over a sub-region of the image. For a sub region r with the left-top corner at (x_1,y_1) and the right bottom corner at (x_2,y_2), the edge density feature is defined as,

$$f=\frac{1}{a_r}\sum_{x=x_1}^{x_2}\sum_{y=y_1}^{y_2}E(x,y)$$

Where a_r is the area of the sub region and is defined as, $a_r=(x_2-x_1+1)(y_2-y_1+1)$. Higher edge density is indicative of number plate region as the presence of characters contributes to more edges. We first search vertically downwards considering overlapping horizontal strips of size 30 x N with a 50% overlap. Horizontal strip size is heuristically determined based on the approximate size of a number plate. A sequence of three high density regions is considered as a candidate region for the number plate. To identify the actual region, we examine for uniformly spaced valleys in the vertical profile in each of the candidate regions. This operation along with an examination of edge strength in vertical direction $E_y(x,y)$ results in identifying the co-ordinates of the number plate.

Difficulties could arise in identifying the number plate region due to additional symbols, graphics or characters other than registration number found on the rear side of the vehicles. However, in current work, we restrict our analysis to the images in which number plate region is well focused and is dominant part of the image.

2.3.3 Character Segmentation

After finding the region of interest the next step is to segment the characters from the plate region in a spatial sequence (which gives the exact number of the vehicle). Segmentation of the numbers written in single line double line or in different orientation is challenge in the segmentation module. The character segmentation (isolation) logic uses connected components and their characteristics [10] in the binarized image to segment the characters. A broad outline of the algorithm is given in Figure 6.

The isolated characters are then size normalized using affine transformation and bilinear interpolation techniques [6]. This helps in comparing the characters with the template (set of all characters and digits used to constitute vehicle registration numbers in India) which are stored in a specified size.

2.3.4 Character Recognition

The segmented characters are recognized using based template matching. Here the isolated character image is compared with the ones in the database and the best similarity is measured. This method measures the correlation coefficient between a number of known character images with the unknown image; the highest correlation is with the reference image closest to the image being compared. The mathematical formulation of the method is explained below.

Let $F_1(j, k)$ and $F_2(j, k)$ for $1 \le j \le J$ and $1 \le k \le K$ represent two discrete images denoting the image to be recognized and template respectively. The normalized cross-correlation between the image pair is defined as follows.

$$R(m,n) = \frac{\sum_j \sum_k F_1(j,k)\; F_2\left(j - m + \frac{(M+1)}{2}, k - n + \frac{(N+1)}{2}\right)}{\left[\sum_j \sum_k |F_1(j,k)|^2\right]^{1/2} \left[\sum_j \sum_k \left|F_2\left(j - m + \frac{(M+1)}{2}, k - n + \frac{(N+1)}{2}\right)\right|^2\right]^{1/2}}$$

For m = 1, 2,…., M and n = 1, 2….., N.

The template database consists of all English capital letters and ten Arabic numerals of fixed size. The most confused characters found in the set are (B, 8), (D, O, 0), (E, F), (S, 5), (Z, 2). The performance of the recognition engine is aided by incorporating the prior information about the format of the Indian license plates like set of state and district codes and its combinations used to form the registration number.

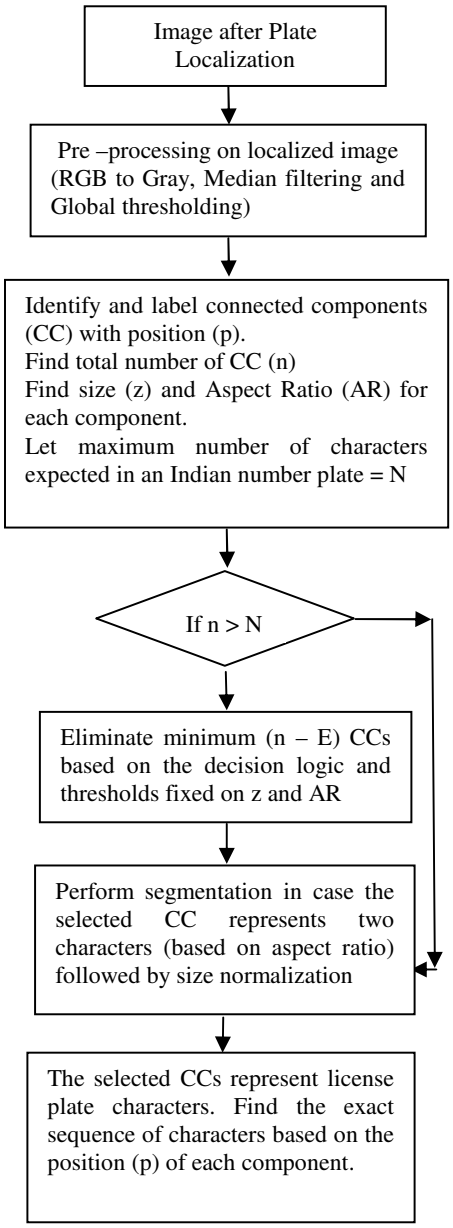


Figure 6. Flow chart of the character segmentation logic

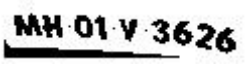
3. EXPERIMENTAL RESULTS

Experiments were performed to measure the accuracy of the recognition engine. The images used for the study are colour images of actual Indian number plates taken under various conditions in the TCS parking lot. All images are taken in 160x120 resolution (which is the lowest resolution of the phone camera) with a Motorola MOTO RAZR V3i handset. The results of image processing algorithms used in the recognition including plate localization, binarization, character segmentation and size normalization are given below. The sample outputs shown in Figure 7 indicate that the recognition engine is capable of handling images with skew or images having information in more than one row.

The performance of the propose system is not affected by the motion of the vehicle. It should be noted that the moving vehicle images are not "blurred" in the traditional sense in image processing; it is more of a "size blur" (see Figure 8).

Original Image

Localized number plate



Binaised image

Character segmentation

Segmented characters after size normalization

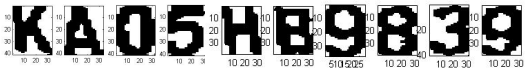
Result 1: License plate characters written in single row

Original Image

Localized number plate

Binaised image

Character segmentation



Segmented characters after size normalization

Result 2: License plate characters written in two rows

Figure 7: Experimental Results

4. CONCLUSIONS AND POTENTIAL APPLICATIONS

The proposed architecture has several applications. Domains we can very well deploy the system include identifying (a) vehicles involved in road accidents, (b) trace stolen vehicles, (c) trace the VIP escorting vehicles, (d) to monitor and issue memo for violation of traffic rules, to record citizen's complaint against a particular vehicle.

Figure 8: Number plate images captured while the vehicle is in motion

The advantages of the proposed architecture are many. It enables a very simple and convenient platform for determining information about any vehicle, anywhere and at any time. It uses commonly available mobile phones (with camera) for information capture and communication with an easy to use interface; providing a wide coverage of use; available to police force even in remote areas where there is mobile phone coverage.

In summary the stakeholders including citizens (general public), traffic polices (to track stolen vehicles, to file the complaint against the vehicle found in a no parking area or to get information about the vehicles in an accident spot), Regional Transport Officer (RTO to verify the tax/insurance remittance details, to track the previous complaints registered against the vehicle) and the insurance agents will also be benefited in different ways to canvas or enable personalized services targeted to their customers (vehicle owners). Different stakeholders and the expected benefit that they get out the services offered by the system are explained below.

Traffic Police as an effective tool for policing: This application will assist the traffic police as a supporting tool for quick investigation to identify stolen vehicles. The automatic cross check with a database of stolen cars or unpaid fines can be used to alert on a newly captured vehicle number. The 'black list' can be updated in real time and provide immediate alarm to the police force. This application can also be used to identify the vehicle violated rules in the road and initiate legal action against it and also able to monitor the suspicious vehicles based on the log collected from the end users through the application.

RTO Officials: This application also help the RTO to identify the vehicles do not have fitness certificate or not having proper taxation, insurance or pollution control certificate at any point of time.

Security Guards (parking, toll gate): Can be used by security guards as an access control for authorized members in a secured area. The events are logged on a database and could be used to search the history of events. This utility can also be used to monitor and manage parking lots. The plate number information can be used to enter pre-paid members and calculate parking fee for non-members. The automatically identified vehicle numbers can be used to calculate the travel fee in a toll-road, or used to double-check the ticket. In order to reduce ticket fraud or mistakes, the application unit can be used to capture the plate number information along with the image of the car. The information may be used to calculate the parking time or provide a proof of parking in case of a lost ticket, a typical problem in

airport parking which have relatively long (and expensive) parking durations.

In this paper, we presented system architecture and a sequel of algorithms for the recognition of vehicle license plate of a vehicle in Indian context. This system is tuned to identify Indian license plates and the system is tested over a large number of images. The proposed system is fast and yields robust recognition results and provides a mechanism to communicate with the user even in regional language. Mobility is the additional advantage of this system compared to the surveillance camera based existing systems.

As a future enhancement, the location information captured along with the number plate images can very well used in vehicle tracking application. The average speed and travel time between two points can be calculated and presented in order to monitor traffic flow and load in a specific area of a city. This system can also be redesigned for multinational vehicle license plates in future.

Almost all existing vehicle number plate recognition systems use one or more fixed cameras which put a restriction on being able to scan only the vehicles passing through a particular point. In contrast, the system proposed in this paper uses "mobile" phone camera to capture number plate images, meaning we have a vehicle plate recognition system which is mobile (we can take it to any location). Additionally, the proposed system facilitates handling vehicles parked anywhere or when vehicles are stopped for inspection by the traffic police. We believe, mobile phone based systems are currently not available anywhere in the world and especially for Indian number plates. Additionally, there is no standard test bed to test the performance of the mobile phone based vehicle number plate recognition system; hence we have not compared the performance of the system with a benchmark. Additionally, the system can not actually be used in a moving vehicle scenario because it is not very convenient to capture the number plate of the vehicle without coming in front or back of the vehicle without disrupting the traffic and putting the person capturing the image in danger.

5. ACKNOWLEDGMENTS

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