Identification of License Plate Number of Vehicle from Video: Mathematical Morphology, Projection & OCR Techniques

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This is to certify that Dissertation entitled

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has been accepted toward fulfillment of the requirement
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CERTIFICATE

This is to certify that the work presented here by **Ms. Swati Bhatt (06MCE001)** entitled "**Identification of License Plate Number from Video: Mathematical Morphology , Projection and OCR Techniques"** has been carried out at **Institute Of Technology, Nirma University** during the period **September 2007 – May 2008** is the bona fide record of the research carried out by her under my guidance and supervision and is up to the standard in respect of the content and presentation for being referred to the examiner. I further certify that the work done by her is her original work and has not been submitted for award of any other diploma or degree.

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ABSTRACT

During past few years, as number of vehicles increased on the roads, managing traffics has been a big challenge for government. To catch and punish traffic offender, lots of man power is required. The automatic surveillance system can make this job easier. As the number plate is meaning to identify the vehicle, Automatic license Plate recognition, (ALPR) is substantial part to make system automated.

ALPR is a system in which, every vehicle passing through the view of camera are monitored. Automated License Plate Reading Systems have been used in transportation applications such as parking lot management; destination studies/trip surveys, cordon studies, travel time studies and automated traffic ticketing systems. As this project is for Indian vehicles, the challenge in this project assumes all vehicles following the Indian traffic rules.

The thesis is divided into two modules: Finding the Number plate from the Frame and character extraction and recognition. Here the number plate extraction is implemented based on the property that there are more horizontal and vertical edges nearer number plate region. The first module implements mathematical morphology in conjunction with projection method, which finds and segments the number plate region. This method gives promising results. For character extraction and recognition template matching and statistical methods are used.

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LIST OF ABBREVIATIONS

ACF	Auto-Correlation Function
ADI	Accumulative Difference Image
ALPR	Automatic License Plate Recognition
BC	Bayes Classifier
CCF	Cross-Correlation Function
CMV	Central Motor Vehicle
ITS	Intelligent Transportation System
k-NNC	k-Nearest Neighbor Distance Classifier
LAG	Line Adjacency Graph
MDC	Minimum Distance Classifier
MDF	Minimum Difference Filter
MV	Motor Vehicle
OCR	Optical Character Recognition
OCR	Optical character Recognition
PNN	Probabilistic neural Network
ROI	Region of Interest
SE	Structuring Element
SW	Sliding Window

1. Introduction

1.1 GENERAL

Information technology is widely used in our modern life caused more demand for intelligent processing. One of the major applications is processing of images and videos captured for various control and security system for transport applications. These conceptual data has many advantages when information is extracted. Extraction of information can be achieved by a human agent, or by special intelligent equipment which is being able to take out valuable information. For automated systems, there is a need to integrate the transportation system and information systems. Because of this, various extraction and recognition techniques have been developed to support transport system and one of this is a number plate recognition system which is used in various traffic and security applications.

1.1.1 Intelligent Transport System

Intelligent transportation system (ITS) refers to efforts to add information and communications technology to transport infrastructure and vehicles in an effort to manage vehicles, loads, and routes to improve safety and reduce vehicle wear, transportation times and fuel consumption and compliance with law.

Intelligent transportation systems vary in technologies applied, from basic management systems such as car navigation, traffic signal control systems, container management systems, variable message signs, automatic number plate recognition or speed cameras to monitoring applications such as security systems, in order to improve the safety, security, efficiency. Image processing is once of the major technique required to implement all these

needs. Image processing which includes image enhancement, noise removal, extraction and identification or matching of objects.

1.1.2 Automatic License Plate Recognition(ALPR)

ALPR is a key technology in ITS where computer vision and pattern recognition are extensively applied. It is found to be very useful in monitoring systems, such as automated toll-pay system, identification of stolen vehicles, travel time data provision, in parking lots, law enforcement and in security applications.

The main task of a number plate recognition system is identification of vehicle number plate (license plate). This automated system will analyze the video captured by a camera (as shown in figure -1.1) at the road side or at the entrance of a car park. The system should find and recognize number plate characters from video frames, in order to extract and decode the number plate, under varying weather conditions. Automatic number plate recognition systems are expected to have numerous applications in traffic surveying and monitoring, e.g. finding stolen cars and controlling access to car parks.

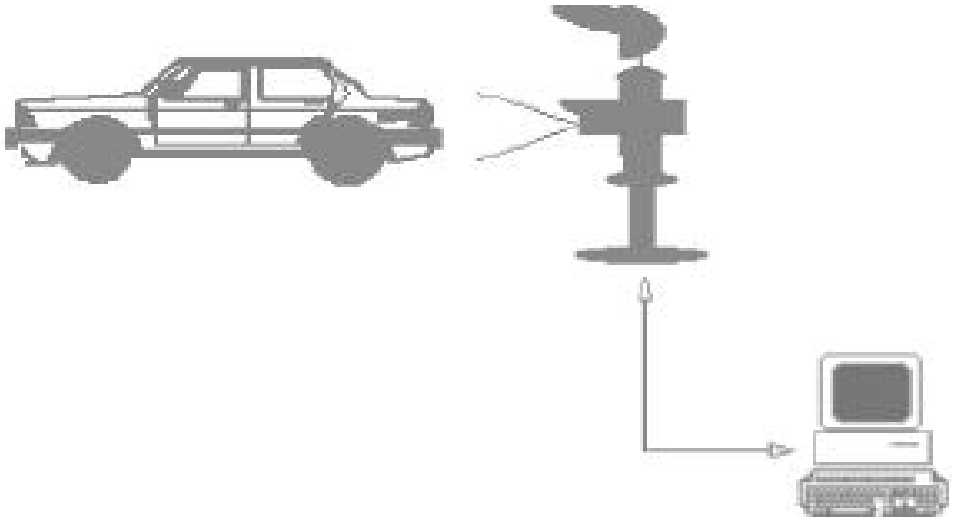


Figure: 1.1 working of ALPR system

1.1.3 Motivation

This system is being developed to provide solution for traffic surveying and monitoring systems, e.g. maintaining the log of the vehicles passing a certain point, number of vehicles and the road network increases it becomes humanly impossible to monitor vehicles violating the rules, organized parking etc. The potential advantage of ALPR technology over manual system is ALPR provides automated detection of number plate. It offers computerized creation of database and can be used to allow or deny the vehicles at the entrance or find an offending vehicle. Interest in applications of ALPR in traffic management has increased in the past decade because ALPR could play important role in ITS.

1.1.4 Application Of ALPR

- Provide automated car park access control by recognizing number plates
- Alert staff to vehicles of interest
- Open barriers and gates automatically
- Log vehicles with multiple images
- Car park auditing / ticketing / management
- Alert for manned gates by displaying details on vehicle registration plate.
- Search for stolen car

1.1.5 Related work

- C. Anagnostopoulos1, et al. [1] has proposed a novel adaptive segmentation technique named Sliding Windows (SW). The method is developed in order to describe the “local” irregularity

in the image using image statistics such as standard deviation and/or mean value. If the ratio of the statistical measurements in the two windows exceeds a threshold set by the user, then the central pixel of the windows is considered to belong to a Region of Interest (RoI). This method adapts the threshold according to the local mean and standard deviation over a window. For identifying the characters Probabilistic neural network (PNN) was trained to identify alphanumeric characters. The training set included the 26 letters of the Latin alphabet (A–Z) and the 10 numerals (0-9). It consisted of 180 patterns created by 5 versions of each one of the 36 characters. For testing the total of 2820 images are sampled, out of which plate segmentation error occurs in 101 images and character classification error in 424 images.

- Cheng Zhang et al [2] suggested method of extracting license plate based on characteristic of characters' connection and projection is proposed and a two-stage approach is designed to deal with images taken from various conditions. In the first stage, the whole image is searched, and the candidate areas are roughly located based on the characters' connection feature. In the second stage, the exactly position of the license plate is detected by characteristic of projection. For tesing purpose 260 images were taken, success detection rate of characters is up to 96% and the average speed is 3ms time-cosuming for a license plate.

- Choudhury A. Rahman [3] suggetsted charactger extraction technique in which character segmentation can be done by detecting the transition from dark to light or from light to dark level. Each character present in the number plate produces a band of gray level. So by detecting the similar gray level bands each character can be segmented. For pattern matching to work effectively, it is needed to find font closely matched with the one used in the number plate. Fifteen different histograms have

been generated for each of the characters for building the library. The pattern matching is done by comparing two ratios for each position in the histograms. One is from the segment and the other is from the library. The ratios are the histogram values of each position to the maximum available in that graph. If the difference of these two ratios is within the value, set by parameter, match count is increased. So by doing this procedure for every horizontal /vertical position of the segment, a match count indicating how closely the segment matches with the character is found out. The algorithm achieves 70% results in 1st iteration, the iterations are repeated till only one result is found.

1.2 PROBLEM STATEMENT

1.2.1 General

In India, all motorized road vehicles are tagged with a unique license number. This special numbers allotted to public transportation such as buses, taxis and auto-rickshaws. The numbers are registered by the organizations which run the services and are usually printed on the front and back side of the vehicle. By law, all plates are based on modern Hindu-Arabic numerals with Roman alphabet, though many states violate this by writing the numerals in the local script.

Car Registration Mark (Rule 50, 51 CMV Rules): The registration number displayed must confirm to following specifications:

- Letters: 4.5 cm high / 1 cm thick
- Numerals: 6 cm high / 1 cm thick
- Space between letters / numerals should not be less than 1 cm.

The color scheme for vehicles (Section 118 MVAct):

For commercial vehicles, the plate has a yellow background and black numbering. For private vehicles a white background with

black numbering is used. Fancy lettering, raised or shining metal numbers are not permitted. The plate should not have any line, or color, or any other kind of marking on it.

Format of the registration is as shown below:

AA 11 BB 1111

Where AA is the two letter state code; 11 is the two digit district code; 1111 is the unique license plate number and BB are the optional alphabets if the 9999 numbers are used up.

For example,

GJ 1 HD 5476

The first two alphabets GJ indicate that the vehicle is from the state Gujarat. The next two are the district (In this case Ahmedabad). HD 5476 is the unique license plate number. Here the initial 0 of the district code is omitted.

1.2.2 Structure of ALPR

This project aims to find number plate from the vehicles, from the video and identify the number using Optical character recognition techniques. Figure 1.2 shows the basic stages to ALPR implementation.

As a vehicle approaches the camera the software takes a video and stores them in a file. Using that video the optimal frame is to be identified using maximum difference frame [4]. The main idea is when vehicle is at the nearest to camera the captured frame is optimum. So when vehicle and so as the number plate starts to exit the frame, this frame can be considered as optimum. The captured frame is operated to identify the number plate region, ROI (Region of Interest).

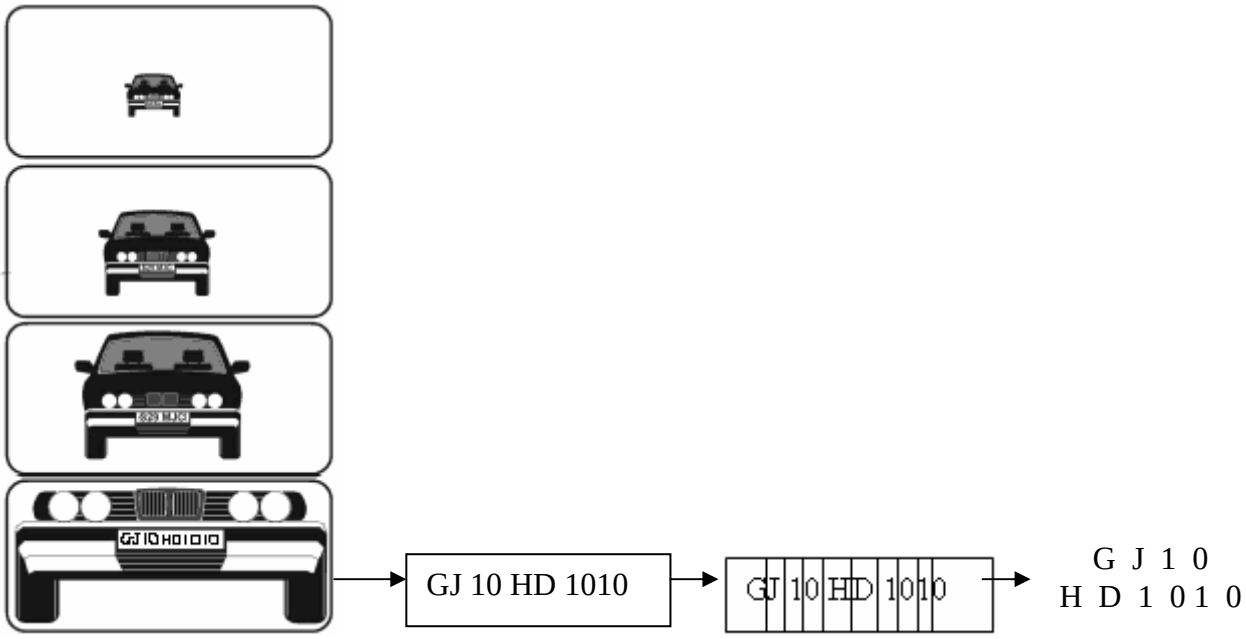


Figure: 1.2 Layout of ALPR

While extracting the number plate other regions having characters or same patterns as plate dynamo and fore-baffle etc, (called candidate regions) may get extracted. So these candidate regions can be considered as noise in this case which need to be removed.

Another problem can be blurring effect is caused by the relative motion between the camera and vehicle. When shutter speed of the camera is slow, as compared to speed of the vehicle, it will look blurred or smeared along the direction of relative motion. Here the camera shutter remains open for an extended period of time and the motion that has occurred over this interval, is visible in a single frame. If the frame with optimal number plate has the blurred number plate, successive procedures will fail to extract the number plate from it. Motion blur can be detected by human or software system but as this is an automated system, needs to implement the way to identify the blurring effect by itself. Blurring effect can be removed by using higher shutter speed cameras or blur removal techniques like edge sharpening.

After taking out the correct license plate region, the character should be separate out. Here the problem of connected components and disconnected component may occur. When the near by characters are connected with each other it is difficult to separate out them.

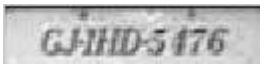


Figure- 1.3 Connected Component

While the disconnected component problem may occur in case of character 'i' where dot (.) is separated from bottom part.

There are some inherent properties of text, such as distinguishing texture, higher contrast against background, and uniform color, making it detectable. By employing these properties, it is possible to detect text regions, removing candidate regions and binarize the image for character recognition.

Then the task of identifying the character comes where letters and numerical are to be found out. Rules of font size and style are widely violated. So the algorithm should able to make out all kind of symbols. The symbol for separator is not fixed, which may add complexity to algorithm. By employing searching operation characters can be separated.

The vital challenge with this work is:

- Some license plate arrangements use variations in font types, sizes and positioning
- Some design or written on the plate other than number
- Poor lighting and low contrast due to overexposure, reflection, weather conditions or shadows
- An object obscuring (part of) the plate, quite often a tow bar, or dirt on the plate
- Plate orientation and sizing – compensates for the skew of the plate and adjusts the dimensions to the required size

- Different style and size of fonts make is difficult to identify the characters.
- One-row or two-rows plate.

ALPR must be able to cope with such differences in order to be truly effective.

1.3 SCOPE OF THE WORK

- The whole purpose of the project is to identifying unique numbers on vehicles not to identify vehicles uniquely.
- Different countries having dissimilar rules for identifying the number plate and thus vehicle. This software aims to identify the plate numbers as per Indian regulations only.
- Here it's assumed that rules of number plate like language of characters and position (font side) is strictly followed by all vehicles.
- Here recognition of number plate of small vehicles like mopeds, bikes and rickshaw is not considered.
- The processing steps identified in this work assume daylight conditions.

1.4 TECHNICAL ASPECTS

For capturing the video, SONY Cyber shot digital camera having 7.2 Mega pixels is used. The camera is located in such a way that font side of the car plate can be captured. The algorithms are developed and tested in MATLAB 7.0 r -14 is used, which provides high level programming environment specially tuned for matrix operations which is advantageous to image processing. Image processing tool, provided by MATLAB, offers a number of easy to access tool for basic operations of image.

1.5 OUTLINE OF THESIS

The thesis is organized as follows. Chapter 2 includes brief discuss of various techniques to identify the optimal frame, number plate extraction and character extraction and recognition. Chapter 3 elaborates implementation techniques for number plate extraction. Here results are achieved for morphological method and statistical analysis through projection method. Character extraction and recognition are included in chapter 4. Cross-correlation, a pattern matching approach is implemented. Results of testing and observations are incorporated in chapter 5. Chapter 6 contains conclusion and future scope of project work.

2. Literature Survey

2.1 GENERAL

The literature analysis is divided into main three parts: 1) Detection of optimal plate using video sequences 2) Number plate Identification from frame and 3) separation and recognition of characters. The first step captures the most favorable frame from the video, results of which affects overall performance of the project. Next, the important in a process of ALPR, is a detection of a number plate area. Character segmentation, can be done by detecting perturb, text area features of transition from dark to light or from light to dark level, in image. And recognition basically performs roll of OCR.

2.2 OPTIMAL PLATE DETECTION

Optimal frame is the frame with the better probability of recognizing number plate than other frames containing the same number plate. When ADI (Accumulative Difference Image) is used for finding optimal frame, it fails, because the vehicle not only moving in horizontal and vertical direction but is comes forward too. So the size of the vehicle and thus the plate increases causes difficulty. The optimal frame can be considered the frame when the vehicle is nearest to camera and thus the plate. So the required frame is, when vehicle starts moving out of the view of camera.

Mid frame and 2/3rd of frame are not very successful to give the optimal frame. In Maximum difference frame method, the size of the vehicle is calculated as difference of the frame from the reference image, which shows entry and exit of the vehicle. Here the processing steps assume the single vehicle in the video frame. The Maximum difference frame gives the best results and finds optimal frame in 80% cases [4].

A method proposed by Xian-Sheng et al [9]includes the video Multiple frame verification technique which reduces false alarm, High contrast Frame averaging (for frame-by counting how many dark pixels around the text boxes) and high contrast blocks (whose neighborhood has high contrast with blocks in the text frame-set) are used for better text character identification.

First of High contrast frame (HCF) is found out. Some text-frames are not suitable for recognition because the background is too complex or the contrast is too low. So to select only "good" frames from the frames set to apply averaging on them. Average those good frames that have contrast of the neighborhood of the texts low. For implementation authors have counted how many dark pixels around this text.

Sometime only the part of the text is readable in the HCF. In this case HCF does not work well. So the text area is segmented into a number of small blocks and selects the corresponding "clearer" blocks in the frame set. Then average the selected clearer blocks and merge the averaged results. So this will help to read each and every word of the text. Instead of applying the text to whole text region, it is applied to each word separately.

This method produces clear text for OCR and recognition rate has been increased about 26% for characters and 28% for words respectively.

2.3 NUMBER PLATE EXTRACTION

License plate location is the first step of the automatically license plate identifying, and also the key step, its result will directly influence the final result of the system. This step is for locating the number plate in the captured image. Number of techniques can be

used in this step e.g. color detection, signature analysis, edge detection, morphological operator, feature based segmentation, searching text from images etc.

2.3.1 Extraction through morphology

A method proposed by Serkan Ozbay [5] to find the plate region, firstly smearing algorithm is used. Smearing is a method for the extraction of text areas on a mixed image. With the smearing algorithm, the image is processed along vertical and horizontal runs (scan-lines). If the number of white pixels is less than a desired threshold or greater than any other desired threshold, white pixels are converted to black. After smearing, a morphological operation, dilation, is applied to the image for specifying the plate location. However, there may be more than one candidate region for plate location.

To find the exact region and eliminate the other regions, some criteria tests are applied to the image by smearing and filtering operation. When the method was tested on 340 images, plate region was successfully extracted from 332 images that are 97.6%.

2.3.2 Extraction through characteristics of text on plate

The problem of identifying the number plate can be considered as identifying the region having text and which contains distinguishable features that can be used to extract text from image.

- Teo Boon Chen has suggested [6], the text regions are composed of dense vertical and horizontal edges of significant strength, regardless of font-color, font-size and language. To extract text, horizontal and vertical profile of the regions with

high aspect ratio is taken and those whose pixel values do not change much within a small area are considered.

To reduce the noise and complex background system uses a variation of the Minimum Difference Filter (MDF).

$$F_{MDF}(x,y) = \max \{ I(x + i, y + j) |_{i^2+j^2<=r^2} \} - I(x,y)$$

This method achieves success ratio of 92.2%. The main drawback in the system is the number of false detections in the video-text segmentation stage, which in turn affects the overall recognition accuracy. It is found to work well on videos with relatively clean background.

- One of proposed technique uses topographical features of characters to extract the character points and use the density of those points to extract the candidate regions for captions [7]. The proposed mask is shown in figure-2.1, where a 7x7 mask is shown, which reduces the computing time when traditional masks are used.

A_4		A_4		A_4		A_4
	A_3		A_3		A_3	
A_4		A_2	A_2	A_2		A_4
	A_3	A_2	A_1	A_2	A_3	
A_4		A_2	A_2	A_2		A_4
	A_3		A_3		A_3	
A_4		A_4		A_4		A_4

Figure: 2.1 Proposed Mask

The algorithm for character extraction method using topographical features is shown below in Fig. 2.1. The value of n changes according to the width of the character stroke, and the value of α determines whether

the current center pixel will be considered as the character region or the background region. The n value is determined by the a priori knowledge about the width of characters to be extracted.

A_1 = center pixel value of character

A_2= average of the 3*3 neighborhood

A_n= average of the n*n neighborhood

If (($A_2 > A_2 + \alpha_1$) and ($A_2 > A_1 + \alpha_2$))... ($A_{n-1} > A_n + \alpha_n$)) OR

(($A_1 < A_2 + \alpha_1$) and ($A_1 < A_2 + \alpha_2$))... ($A_{n-1} < A_n + \alpha_n$)

Then Character

Else

Not character

Where n= size of mask and $\alpha_1, \alpha_2, \ldots \alpha_n >= 0$

Figure: 2.2 Algorithm for character stork extraction

In order to form individual character regions those character points that are close to each other horizontally are merged using merging distance n*2, depends on stroke width (or mask size) n. The 2 stage post-processing method is offered to decide whether a candidate has characters or not.

In the first stage, the size and other characteristics of the text lines are analyzed to remove non-text regions. If the area, width and height of candidate text regions are too small or high, the corresponding regions are discarded. Next, the width-to-height ratio of the blocks is calculated. If it exceeds limits, i.e. dose not lie between min-ratio and max.-ratio, the corresponding regions are also discarded.

This experiment shows that the result of extracting candidate areas was 100% when this approach was applied to 13 scenes with 1983 frames. Finally, 99% of extracting candidate areas was acquired

when the verification was performed with the combination of various kinds of background and character colors. Problem needs a method to obtain the **α** values by training and prior knowledge about stroke width is required.

2.4 CHARACTER SEGMENTATION

In the segmentation of characters in license plate is segmented into its constituent parts obtaining the characters individually [6]. Firstly, image is filtered for enhancing the image and removing the noises and unwanted spots. Then dilation operation is applied to the image for separating the characters from each other if the characters are close to each other. After this operation, horizontal and vertical smearing is applied for finding the character regions. The next step is to cut the plate characters and is done by finding starting and end points of characters in horizontal direction. Here success ratio is 96%when applied to 340 images.

2.5 CHARACTER RECOGNITION

Template matching is an effective algorithm for recognition of characters. Before recognition algorithm, the characters are normalized [6]. Normalization is to refine the characters into a block containing no extra white spaces (pixels) in all the four sides of the characters.

For matching the characters with the database, input images must be equal-sized with the database characters. The extracted characters cut from plate and the characters on database are now equal-sized. The next step is template matching. The character image is compared with the ones in the database and the best similarity is measured.

To measure the similarity and find the best match, a statistical correlation is used. Correlation is an effective technique for image recognition. This method measures the correlation coefficient between a number of known images with the unknown images of same size or parts of an image with the highest correlation coefficient between the images producing the best match. There are two forms of correlations: auto-correlation and cross-correlation. Auto-correlation function (ACF) involves only one signal and provides information about the structure of the signal or its behavior in the time domain. Cross-correlation function (CCF) is a measure of the similarities or shared properties between two signals. Since there are two signals as unknown input image and known database image in this system, cross-correlation is used.

Let F1 (j,k) and F2 (j,k) for 1 (j,J) and 2 (k,K) represent two discrete images denoting the image to be searched and the template respectively. The normalized cross correlation between the image pair is defined as:

$$R_{m,n} = \frac{\sum_j \sum_k F1(j,k) * F2(j-m+(M+I)/2,\ k-n(N+1)/2)}{[\sum_j \sum_k F1(j,k)]^2]^{1/2} [\sum_j \sum_k [F2(j-m+(M+I)/2,\ k-n(N+1)/2)]^2]^{1/2}}$$

For m=1, 2… M and n=1, 2….N, where M and N are odd integers.

Because of the similarities of some characters, there may be some errors during recognition. The confused characters mainly are B and 8, E and F, D and O, S and 5, Z and 2. To increase the recognition rate, some criteria tests are used in the system for the confused characters defining the special features of the characters. With these features of characters and applied tests during recognition algorithm, recognition rate is increased with the minimum error. Characters are effectively recognized with ratio of 98.8%.

One of the ways to extract the characters is line adjacency graph (LAG) [8]. It is a representation of the image pattern as a list of

black or white segments. Assuming text having dark in color with light back ground, a white segment is defined to be a sequence of consecutive white pixels in a row, which can be denoted by the triple <r, L, R>, where r is the row number of the segment, L is the column number of the leftmost pixel of the segment, and R is the column number of the rightmost pixel of the segment. White segments w1 = <r1, L1, R1> and w2 = <r2, L2, R2> are said to be friends, if and only if, they lie on adjacent rows, and w1 and w2 have overlapping columns.

If a white segment w in row r has N friends in row r-1, then w is said to have N north friends. Similarly, if w has S friends in row r+1 then w is said to have S south friends. Therefore, all white segments can be delineated by its 5-tuple <r, L, R, N, S>, which contains explicit information on its location and the number of north and south friends of the white segment. When this 5-tuple is calculated for all white segments in image, the whole pattern is known as the white line adjacency graph (white LAG). Then region-labeling on the LAG is used to locate connected components. Line segments with the same label are extracted one by one and are grouped into characters or non-characters (noise).

A database is constructed with left, right, top and bottom side-profiles of sample characters. Fig. 2.3 shows a sample of four side-profiles of character 'a' in Helvetica font. The candidate characters are recognized by matching their side-profiles against the database. However, a problem commonly encountered in video-text is merging of characters, i.e., adjacent characters may be touching each other making it difficult to locate individual characters in a text line.

To separate each individual character in the string, the right side-profile of the merged part is compared with the samples in the database. The possible width of the right-most character is approximated from the matched character and the right-most

character is cut out from the right side of the string accordingly. The method is repeated from right to left till all the individual characters in the string are separated.

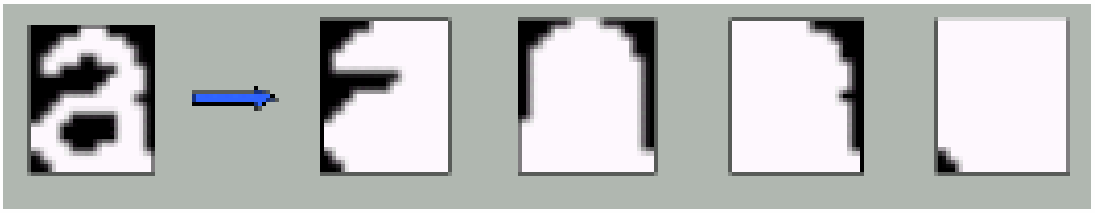


Figure: 2.3 Left, top, right and bottom side-profiles of character 'a' [8]

3. Number Plate Detection

3.1. INTRODUCTION

The problematic area of identifying the number plate includes algorithms that are able to detect a rectangular area of the number plate with increased occurrence of horizontal and vertical edges in an original image. While extracting the number plate the other regions having same kind of pattern will also get extracted, considered as noise. So verifier is required to detect ROI that is number plate, and remove noise that is candidate regions. The detection of the accurate location of a license plate from a vehicle image is considered to be the most crucial step of an ALPR system, which greatly affects the recognition rate and speed of the whole system. The character recognition carried out after having the best plate candidate approved.

3.2. MATHEMATICAL MORPHOLOGY

Mathematical morphology is a part of digital image processing which is concerned with image filtering and geometric analysis by using structuring elements (SE). Mathematical morphological operators often take a binary image and a structuring element as input and combine them using a set operator (intersection, union, inclusion, complement). The mathematical details are explained in Mathematical Morphology.

Usually, the structuring element is sized 3×3 and has its origin at the center pixel. It is shifted over the image and at each pixel of the image its elements are compared with the set of the underlying pixels. If the two sets of elements match the condition defined by the set operator, the pixel underneath the origin of the structuring element is set to a pre-defined value (0 or 1 for binary images).

3.2.1. Operations performed

Here, morphological method is used to detect the candidates of the license plate region.

Step: 1 Thresholding: The image is converted to binary image. If the image is color image it's converted to gray scale first.
Here Otsu's method of global thresholding is used to select the threshold value and to convert an intensity image to a binary image.

Step: 2 Dilation: The image is subjected to dilation. The effect of the operation on a binary image is, it gradually enlarge the boundaries of regions of foreground pixels (i.e. white pixels, typically). Thus areas of foreground pixels grow in size while holes within those regions become smaller.

$A \oplus B = \{ z \mid [(B)_z \cap A] \quad A \}$

Where A= original image, B = Structuring element

0	1	0
1	1	1
0	1	0

Figure – 3.1 structuring element used for dilation (4-neighborhood of the origin pixel

Step: 3 Noise Removal: Remove all the are which are smaller in size as compared to surrounding regions. That will remove all the candidate regions, appearing as noise, which are lesser in size. So that probable set of candidate regions is reduced.

Step: 4 Erosion: Erosion operation is now applied to the image. This operation does local comparison of a shape, depending upon shape of the structuring element. Here the size and shape of the SE is crucial which affects the compression of the shape.

$$A \ominus B = \{z \mid (B)_z \subseteq A\}$$

1	1	1
1	1	1
1	1	1

Figure –3.2 Structuring element used for dilation (4-neighborhood of the origin pixel)

If for every pixel in the structuring element, the corresponding pixel in the image underneath is a foreground pixel, then the input pixel is left as it is. If any of the corresponding pixels in the image are background, however, the input pixel is also set to background value.

(a) (b)

Figure-3.3 (a) Original Images (b) Resulted Image having all possible areas

Here results shows that along with number plate region noise is also get extracted. So the method needs to be adopted to remove the noise region. The method works well with suitably clear images, having number plate easily readable.

3.3. PROJECTION METHOD

Here is a horizontal and vertical projection of an image into the axes x and can be used to detect the text region that is number plate region.
It is observed that number plate region contains the high density of edges as compared to other areas. When Sobel edge detector (figure-8) of 3x3 convolution mask is applied to the image, horizontal and vertical edges get exhibited (figure 9)

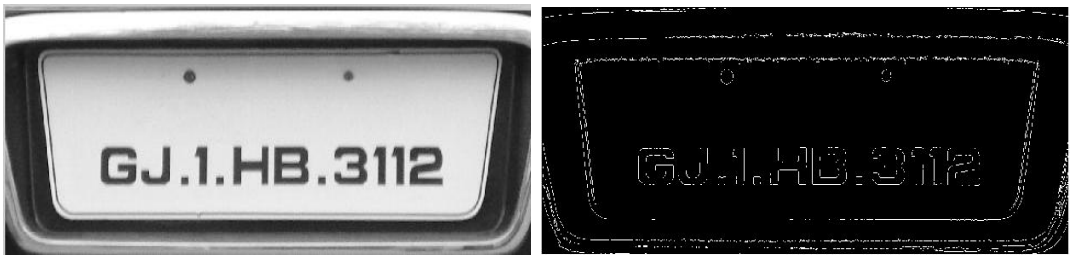
-1	-2	-1
0	0	0
1	2	1

(a)

-1	0	1
-2	0	2
-1	0	1

(b)

Figure- 3.4 Sobel operator (a) Horizontal edge detector (b) Vertical edge detector



(a) **(b)**

Figure 3.5 (a) Original Image (b) Edges in the image

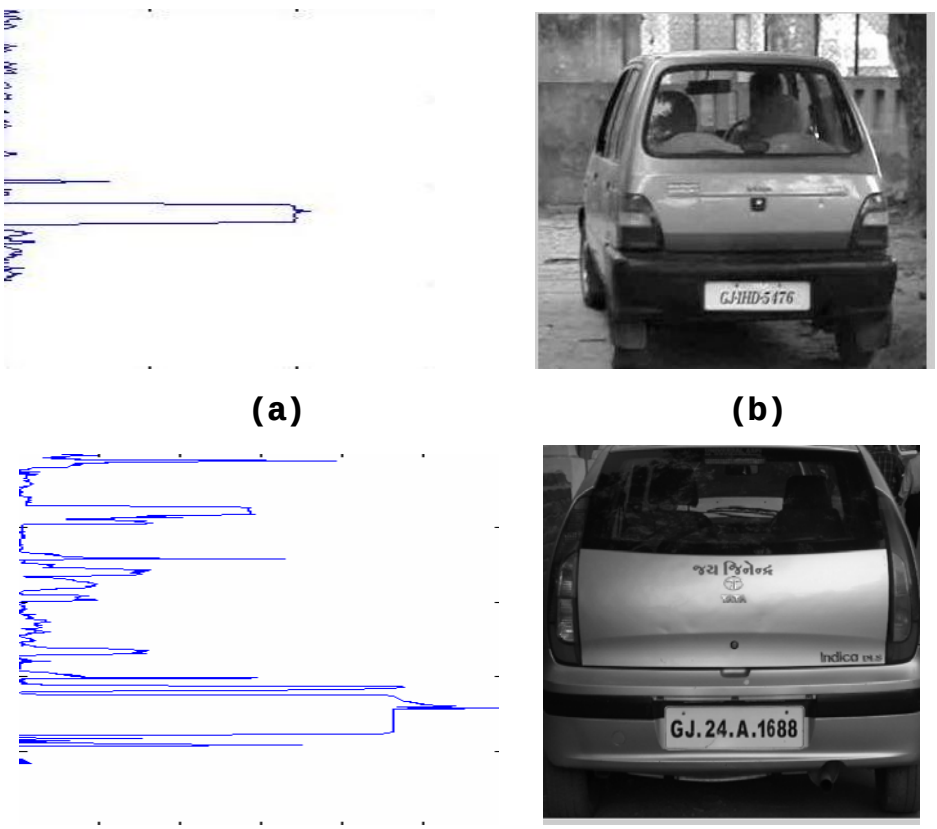
The high density of horizontal and vertical edges on a small area is in many cases caused by contrast characters of a number plate. Here simple edge based methods can be used to compute the area having

denser edges. The number of pixels greater than some threshold can be extracted, using horizontal and vertical projection. When horizontal and vertical projection may lead to forged license plate area because of chains, plate dynamo and fore-baffles having same kind of pattern which also shows high density of edges.

So when projection method is combined with morphological method, gives better results.

3.3.1. Operations performed

The input image is defined by a discrete function F(x, y). Then, a vertical projection Py is a summation of all pixel magnitudes in the yth row of the input image. Similarly, Px, a horizontal projection at a point x of that function is a summation of all magnitudes in the xth column.



(a) (b)

(c) (d)

Figure-3.6 (a) & (d) Original images (b) & (c) Vertical projection

Mathematical representation of the horizontal and vertical projection is,

$$P_x(x) = \Sigma F(x,i) \quad , i = 1:n$$
$$P_y(y) = \Sigma F(j,y) \quad , j = 1:m$$

where n and m are dimensions of the image.

Here figure 3.6 shows the vertical projection of the image on the right side. When sum of the row is calculated over the whole image, maximum value of sum is at number plate region. The reason behind it is when image is converted to binary image most of the background pixel is assigned black value while the number plate region contains maximum number of pixels having value 1. This method depends very much on the light illumination conditions and if number plate is in dark region (due to shadow of some other vehicle) and some part of the car body get brighten dues to sun light.

The purpose of the vertical projection is to extract the plate. So need to define threshold value in such a way that sum of the pixels exceeds only in number plate region will be pull out. The threshold should be dynamic so that will adapt itself for the image and work for all. Here it is also observed that if only projection is applied, to extract the number plate, the noise region which is brighten because of lighting region, drawn out. So the projection is applied on the results achieved from previous method. Here experimental threshold value is set to two third of the maximum value which gives optimum results.

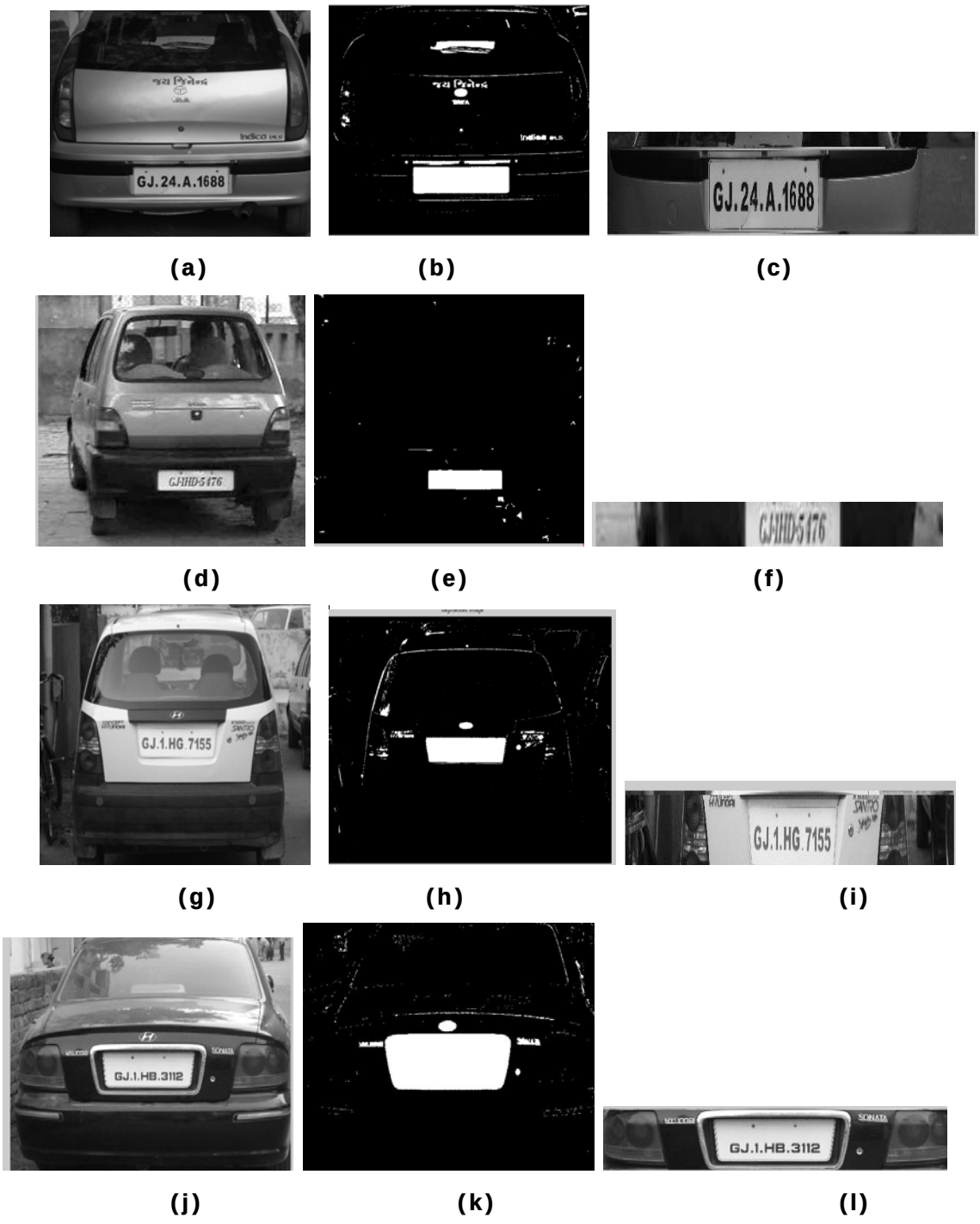


Figure-3.7 (a, d, g, j) – Original images (b, e, h, k) – results achieved with noise region, when applied Morphological technique (c, f, i, l) – Strip containing Number plate only

From the above figure it is obvious that results are improved when the combination of the above two methods are used. Some other extracted plates are shown below figure.

Figure-3.8 Number Plates extracted successfully

After applying the appropriate threshold value, figure 3.8 shows the extracted regions. It can be observed that in figure 3.8 (b) some area which is having value greater than threshold is also extracted. In figure 3.8 (d) some part of the number plate is not extracted because the projection is applied on results of mathematical morphology, which is unable to extract the whole plate region. Figure 3.9 shows a result which completely fails to extract the RIO.

Figure- 3.9 (a) Original image (b) extracted ROI

The possible failure of the method can be observed in figure, that some bright portion on car body also get extract during processing which causes the threshold value to be very high, so that number plate region is not pulled out. To remove this kind of failure histogram equalization can be used.

4. Character Segmentation and Recognition

4.1 INTRODUCTION

The next step after the detection of the number plate area is a segmentation of the plate. The segmentation is also one of the most important processes in the automatic number plate recognition, because all further steps rely on it. If the segmentation fails, a character can be improperly divided into two pieces, or two characters can be improperly merged together.

Optical character recognition (OCR) does the task of character segmentation and identification. Various OCR algorithms have been proposed to achieve better recognition results. These algorithms include template matching, image signatures, geometric features, shape-based image descriptors, neural network classifier etc.

4.2 PATTERN MATCHING BY CORRELATION

The objects to be recognized are characters, written on the license plate. Under real conditions, like motion blur, characters are joined to each other, which cause difficulty in isolating a single character. This problem is referred as isolation of connected components. The pattern matching is considered as a suitable technique. It does the character extraction and recognition simultaneity, and avoids isolation of the single character.

To implement this technique a database of all possible patterns is created. The vehicle license plates there are Arabic letters and numbers. So there must be two kinds of templates. Each template is matched against the image. This project work built templates with gray level images. In the acquired image the character does

not exactly match the prototype, so normalized cross-correlation operator defined in the discrete case, as follows, is used.

$$C_{fg} = \frac{\sum \sum (f-f)(g-g)}{\sqrt{\sum (f-f')^2} \sqrt{(g-g')^2}}$$

Where g is a generic template and g' is its average gray level, f is a sub-image of the acquired image having the same size of the template and f' is its average gray level. Here the value of Cfg is checked against threshold value. The pixels having values greater than threshold are considered to be matched pixels.

Figure –4.1 Template used for pattern matching

According to our observation from the acquired images, we define the template size as 10 x 10. Templates are designed using a graphical tool.

4.3 RECOGNITION ALGORITHM

When above method is applied, the achieved results are shown in the figure. Moreover, since the first two characters are letters so it is only needed to compare these characters with the pattern of letters from A-Z only. Similarly, for the last three to four characters, it is only needed to compare them with the pattern of digits from 0-9. This reduces computational time. When only one cluster of connected pixels having value greater than threshold is resulted, it is considered to be recognized character.

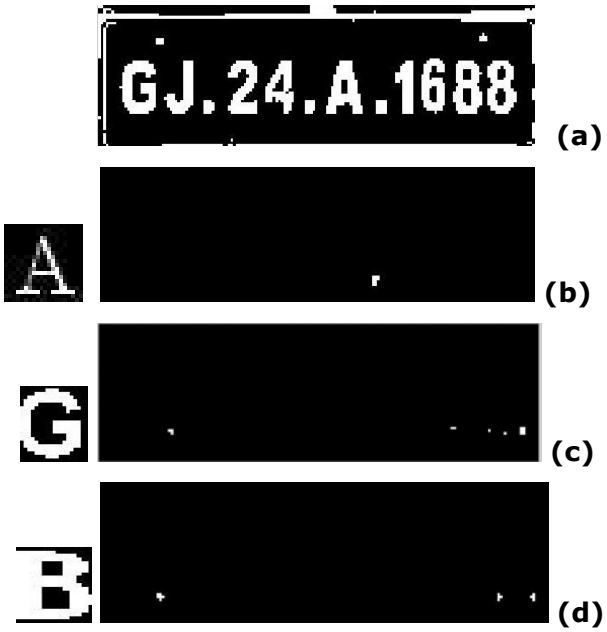


Figure –4.2 Results of cross-correlation
(a)-Original image (b)-Template (c)- Maximum threshold achieved

Here it is observed in figure- 4.2 (b) that for character 'A' only one region is extracted. While for character 'G' there are three regions are extracted. This reason behind it is that bottom part of the character 'G' having similar pattern as with digits '6' and '8'. So the regions at these digits also get extracted. The similar kind of results is achieved in figure-4.2 (d).

- **Dealing With Few Characters Easy To Be Confused:**

Some characters with similar shape are easy to be confused in the pattern matching, such as G, O, Q, D and B, 8, 0 and so on as mold of characters are similar. The differences between them are very imperceptible. Here prior knowledge of character orientation is used to resolve the ambiguity between characters such as: digit '0' and the letter 'O', digit '8' and letter 'B'.

- **Dealing with confusion between characters and numeral:**

This can be removed by following the number plate rules. As mentioned earlier, the commercial number plate can be divided into four parts.

AA DD AA DDDD

A stands for letters, D for Numerical values

So number plate can be divided into four parts: Letters, numerals, letters, and numerals. So whenever the symbol 'G' is being matched against number plate, it cannot be in region of numerals. Division of the number plate can be done on the basis of overall size of plate.

- **Dealing with similar kind of letters:**

Here character 'Q', 'O' are alike. Generally, In India, currently, no state has 'Q' as starting symbol. So this can be avoided.

This confusion can be solved by identifying the next character on the plate. The first two characters are always of form a pair. So if that pair does not occurs for one possible template, it can be assumed to be other symbol.

Foe identification of the number all the temples are matched against the number plate image. The co-ordinates of the center of the pixels, having value greater than threshold, are stored in a file. After all matches are performed, the coordinates are sorted and accordingly the number is stored into a text file.

4.4 CHARACTER EXTRACTION

The characters can be extracted individually by finding connected components in number plate. When thinning algorithm is applied to the number plate, is removes pixels on the boundaries of character but does not allow character to break apart. The remaining pixels make up the image skeleton. Results attained are shown in figure below.

(a) **(b)**

Figure 4.3 (a) Number plate (b) Skeleton

It is noticed that last image does not show the appropriate results as some of the characters (G and J) are still contacted in resulting image. This method cannot be applied to separate out the characters.

So, a horizontal projection of a number plate for the segmentation is used. If we assume only one-row plates, the segmentation is a process of finding horizontal boundaries between characters. The thresholding is used to separate dark foreground from light background with non-uniform illumination. After the thresholding, a horizontal projection of the plate computed. This projection is used to determine horizontal boundaries between segmented characters. These boundaries correspond to peaks in the graph of the horizontal projection (figure 4.4.c).

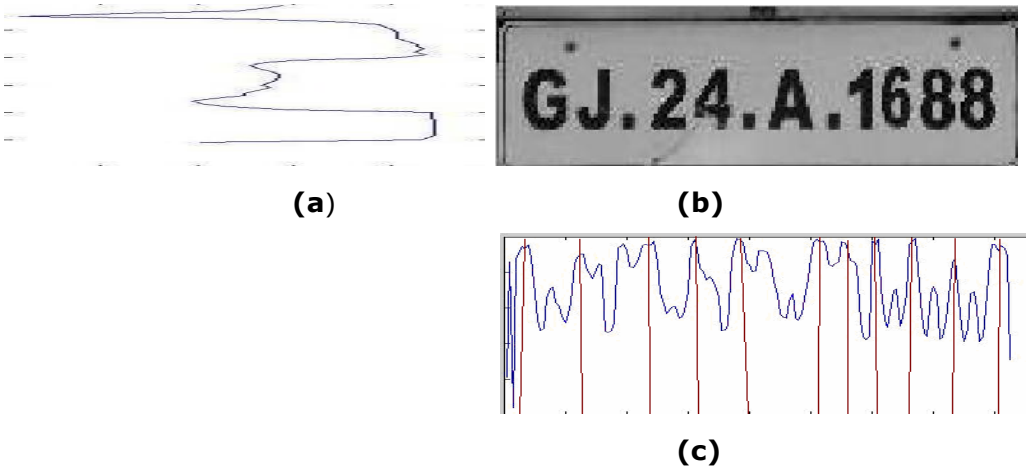


Figure 4.4 (a) Vertical projection of Number plate after applying threshold (b) Original number plate (c) Horizontal projection of plate with detected peaks. Detected peaks are denoted by dotted vertical lines.

Here vertical projection is used to take out individual characters while horizontal projection can be used to cut the characters along the width of characters. So that final extracted characters are cut along with their width and height only, no background region is captured. The extracted characters are stored into an image file for further processing.

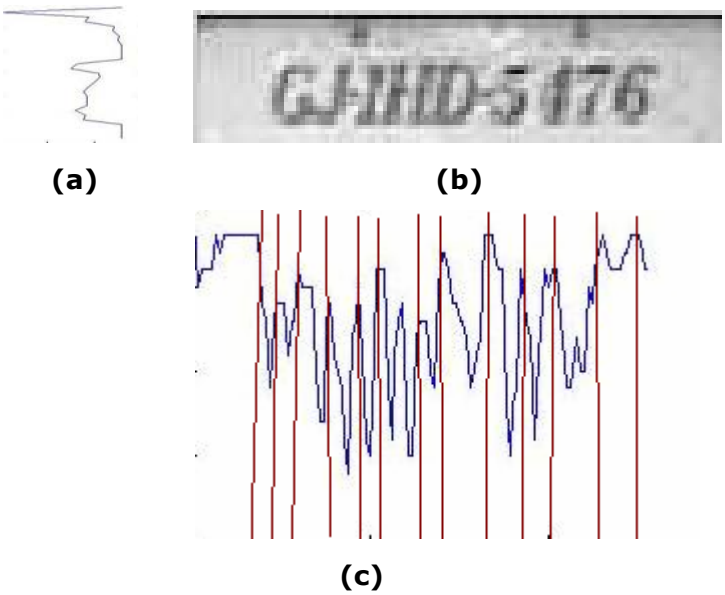


Figure- 4.5 (a) Vertical projection of Number plate after applying threshold (b) Original number plate (c) Horizontal projection

Here noticed that still it is difficult to extract the extract characters. So better method need to be employed. The possible reasons for connected components are blurred image (due to motion blur) and low resolution of camera.

4.5 PATTERN MATCHING THROUGH STATISTICAL ANALYSIS METHOD

For character identification OCR extracts proper image features, computes the "distances" between the extracted image features and the known feature vectors stored in the image model library, and recognizes the image according to the degree of similarity between the loaded image and the image models

For creating the templates, the character size and font is kept same and each character is sliced along with the farthest boundary of character. Each character is also designed manually using drawing toolbox.

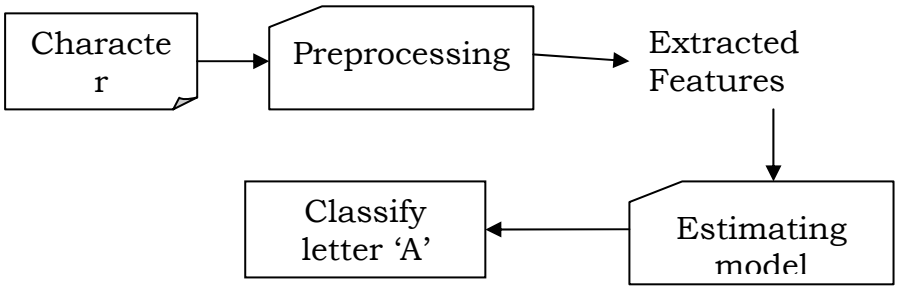


Figure- 4.6 Basic procedure of OCR

In particular the steps are, feature extraction, classification and feature selection, which are further described below.

4.5.1 Feature Extraction

The first step is the feature extraction step, which is the transformation of patterns into features that are regarded as a compacted representation. The statistical image features are Mean, Variance, Skewness, Second Moment, Third order moment, Smoothness, Correlation, and Entropy etc.

4.5.2 Classifier

The classification step, which corresponds to the matching stage of object recognition systems, assigns each loaded character image to one of the possible image models. The decision is made on the basis of the similarity measure.

For classification of the characters the possible ways are described bellowed.

1) The Minimum Distance Classifier (MDC), which employs as classification criterion the minimum Euclidean distance between the unknown entry and the mean values of each of the other classes,

2) The k-Nearest Neighbor Distance Classifier (k-NNC), where the classification criterion is the minimum Euclidean distance between the unknown entry and the k-Nearest Neighbor elements of any other class.

3) The Bayes Classifier (BC), which minimizes the expected cost of misclassified data.

4.5.3 Feature Selection

Those features of segmented character, which achieve the best classification rate, should be used in the pattern recognition process. This phase aims to reduce the features set to a subset, which consists only of meaningful information (i.e. features which characterize best) about the images that need to be classified.

4.5.4 Model estimation

Each character tends to have typical features cluster together. A given number should look about the same for each realization

Figure- 4.7 Number Plate Template

Here Average intensity (mean), Average contrast (variance), measure of smoothness, third moment and entropy is calculated for model estimation. From the tables it is observed that the combination of average intensity, average contrast and third moment can be used as model parameters. But still there is some variance in all three parameters when temple is compared to characters extracted from the number plate. The processing step assumes same size and style of the characters of template and extracted characters. As well as for all the characters of the number plate should be almost same.

Char	Average Intensity	Average Contrast	Measure smoothness	Third moment	Measure of Uniformity	Entropy
G	38.953125	87.432863	0.105196	20.666226	0.286777	3.222871
J	44.800000	93.458500	0.118419	22.116491	0.226953	3.258566
1	92.093750	119.233059	0.179407	15.603514	0.161953	3.677222
0	54.779297	100.876317	0.135318	22.745573	0.202499	3.561383
H	59.283203	104.367626	0.143479	22.780200	0.189049	3.596370
B	61.951923	105.297735	0.145674	22.278520	0.213572	3.583978
4	65.108333	107.653957	0.151269	22.113102	0.200864	3.498356
5	50.366667	96.609755	0.125520	22.101097	0.181155	3.700250
6	44.738839	92.731809	0.116798	21.757261	0.253697	3.271693
7	46.740741	95.062491	0.122018	22.394086	0.258097	3.124249

Table-4.1 Features for number plate

Ch	Average Intensity	Average Contrast	Measure smoothness	Third moment	Measure of Uniformity	Entropy
G	43.665344	83.612393	0.097076	16.683348	0.174512	4.353281
J	30.225806	77.710260	0.084978	17.671083	0.395007	2.371610
1	72.494983	110.958197	0.159196	20.555236	0.145535	3.825426
0	58.886364	94.351215	0.120418	17.822107	0.147178	4.423190
H	60.318841	105.977961	0.147284	23.212116	0.228500	3.071619
B	88.506803	108.981049	0.154442	13.340351	0.083484	5.002188
4	50.018947	94.189896	0.120056	20.270975	0.271942	3.523318
5	53.314480	92.012114	0.115201	18.009733	0.198348	4.134711
6	45.401261	84.495318	0.098933	16.544684	0.183903	4.237739
7	49.692547	90.098024	0.110984	17.929549	0.228213	3.746231

Table-4.2 Features for template

The better results can be achieved when all the vehicles strictly follow the Indian number plate rules mentioned earlier. So, the exact size and style of the character can be used as prior knowledge.

5. Concluding Remarks

5.1 SUMMARY

With an aim to study to extract number plate from the videos of vehicle, this study was conducted and tested in MATLAB 7.0 release 14 by combination of mathematical morphology and projection method to extract number plate location and cross-correlation for character recognition.

In order to acquire number plate region, mathematical morphology was implemented where noise region also get extracted along with number plate region. For improvement of the results Vertical and horizontal projection was carried out. Cross-correlation was applied on extracted number plate, which identified the characters. Statistical methods for characters' identification, was suggested. The same can be used to combine with cross-correlation to improve the overall efficiency of the system.

5.2 CONCLUSION

The project implements the number plate identification and character extraction & recognition. Following conclusions are drawn:

In identifying plate region from captured image, combination of morphological method and projection method, is applied. The number plate recognition step achieves success rate around 70%.

Cross-correlation is used for character identification which can extract and recognize the characters in all most all plate when some constrains about number plate rules are applied. Statistical method processing for character recognition assumes strictly following traffic rules and highly depended on size and style of the characters.

For universal application of the project statistical feature data can be feed as input to the neural network.

A number plate consisting of two rows (e.g. first row contains state & district code and second row contains unique identification number), vertical projection with appropriate threshold and/ or scan line method can be used to extract rows and then characters.

5.3 FUTURE WORK

One of the first recommendations for future work is the acquisition of a larger database of videos on road. Some basic image enhancement techniques can be applied for blur removal and remove connectivity between characters. The number plate detection techniques are applied on gray scale image, when number plate with background color other than white/yellow is processed, the success rate may decease. The system described in this thesis requires upgrading the estimation model for statistical data. The combination of statistical method with cross-correlation can be used for character identification, which can improve the results.

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