Eagle Eye
Automatic Number Plate Recognition

Submitted By

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11BCE090

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

INSTITUTE OF TECHNOLOGY

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Eagle Eye
Automatic Number Plate Recognition

Major Project

Submitted in partial fulfillment of the requirements

for the degree of

Bachelor of Technology in Computer Science and Engineering

Submitted By

Saloni Shah

(11BCE090)

Guided By

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DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

INSTITUTE OF TECHNOLOGY

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AHMEDABAD-382481

May 2015

Certificate

This is to certify that the major project entitled ”Eagle Eye-Automatic Number Plate Recognition” submitted by Saloni Shah (11BCE090), towards the partial fulfillment of the requirements for the award of degree of Bachelor of Technology in Computer Science and Engineering of Nirma University, Ahmedabad, is the record of work carried out by her under my supervision and guidance. In my opinion, the submitted work has reached a level required for being accepted for examination. The results embodied in this project, to the best of my knowledge, haven't been submitted to any other university or institution for award of any degree or diploma.

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Statement of Originality

I, Saloni Shah, Roll. No. 11BCE090, give undertaking that the Major Project entitled ''Eagle Eye-Automatic Number Plate Recognition'' submitted by me, towards the partial fulfillment of the requirements for the degree of Bachelor of Technology in Computer Science & Engineering of Institute of Technology, Nirma University, Ahmedabad, contains no material that has been awarded for any degree or diploma in any university or school in any territory to the best of my knowledge. It is the original work carried out by me and I give assurance that no attempt of plagiarism has been made. It contains no material that is previously published or written, except where reference has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere; it will result in severe disciplinary action.

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Abstract

Automatic Number Plate Recognition (ANPR) is a system designed to automatically detect and recognize number plates, without direct human intervention. It is an important field of research related to security. Due to low resolution of surveillance cameras, it becomes difficult to accurately recognize the number plates. One solution is to install high resolution cameras, but unfortunately, the costs of setting up such cameras are very high. Instead, by using image processing techniques, better and accurate output can be obtained at low cost. The algorithm consists of four phases: i) pre-processing, ii) localization and extraction of number plate, iii) character segmentation and iv) character recognition [1]. In this report, algorithms that can be used at each phases are described, and compared based on outputs at those stages.

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Chapter 1

Scope

The scope of project is to recognize the number plate of vehicles as part of institute's surveillance system. For this, various image processing techniques such as, morphological operations, thresholding, filtering, connected component analysis, segmentation, optical character recognition, etc. are used. In this report, algorithms that can be used to perform the four phases are described and compared. The algorithms are implemented in MATLAB with 3 different set of images. The first and second sets contains images which are properly and not properly illuminated respectively. Both these sets have little amount of skew. While the third set contains images which are highly skewed.

Chapter 2

Introduction

The development in image acquisition techniques has resulted in efficient cameras at reasonable price[2]. Nowadays, image processing techniques are widely used for varied number of applications, most of them being related to security. Automatic number plate recognition, face recognition, gesture recognition, finger print recognition, etc. are some of such applications which use image processing techniques for security, surveillance and authentication purposes. The applications of automatic number plate recognition vary from automatic parking facilities, restricted areas reserved for VIP members, traffic monitoring and control, automatic toll sensors, detecting vehicles involved in theft, etc.[1][3] But unfortunately, many factors such as illumination conditions, weather, font type and size, damaged plates, angle of camera, resolution of camera and the distance between the camera and number plate make it difficult for ANPR systems to give accurate and efficient results. Even though most of the above mentioned factors can be overcome using certain image processing techniques, these factors still remain the reason behind why a general ANPR system can't be implemented.

Most of Indian plates follow a standard specification: first two letters indicate the state code, the next two digits indicate the district code, followed by a unique four digit number. If the four digit number runs out, a letter(s) is prefixed and then two letters and so on. The current format of number plate also consists of international oval 'IND' with a blue square on top of it. Figure 1 below shows one such standard number plate.

Figure 1: Indian number plate

The basic algorithm for ANPR consists of four phases: i) pre-processing of image, ii) localization and extraction of number plate, iii) character segmentation and iv) character recognition, as shown in Figure 2. In pre-processing of the input image, enhancement techniques such as skew correction and filtering is done so that the number plate can be easily localized and its characters properly segmented in phases (ii) and (iii). To localize a number plate, again enhancement techniques such as morphological operations are used to minimize the number of probable areas of number plate. Once it is localized, the region of interest is extracted from the image. Using connected component analysis, character segmentation is

carried out. And finally, using optical character recognition characters of number plate are recognized.

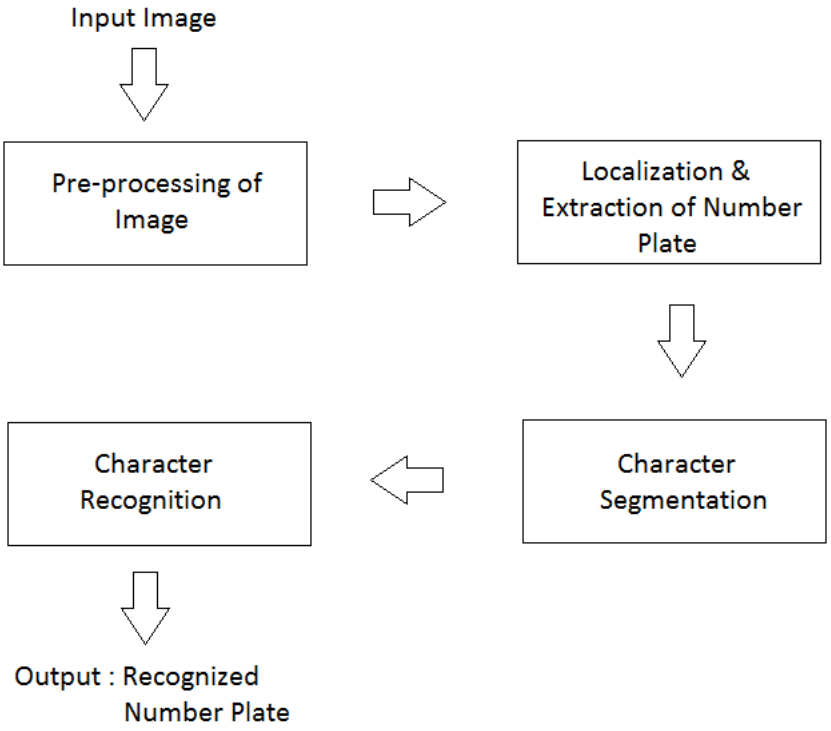


Figure 2: Basic flow of ANPR

Chapter 3

Literature Survey

There are many different algorithms that can be used at various stages of ANPR. Many techniques have also been proposed for number plate localization and character segmentation.

1. Pre-processing:

   Most of the algorithms related to pre-processing phase include converting the image to grayscale from RGB image, and apply median filter on it to remove the noise. Manisha Rathore and Saroj Kumari et al [4] have only converted RGB image to grayscale image. The authors mentioned in references [3] [5] [8] have used both conversion to grayscale and thereafter median filter to enhance their input image. While Sahil Shaikh, Bornika Lahiri, Gopi Bhatt and Nirav Raja et al [6] have used techniques like variance enhancement to improve illumination conditions, unsharp masking and brightness normalization apart from grayscale processing and median filtering to enhance the number plate more efficiently. Enhanced shadow removal method can also be used to enhance the plate region.[15] Depending on the illumination conditions, most of the times grayscale processing and median filtering works fine for enhancing the number plate, which are the methods that have been used in this report. Only if the number plate is too dark or there is high amount of shadow present on number plate, more enhancement techniques are required.

2. Localization and Extraction of Number Plate:

   Sarbjit Kaur and Sukhvir Kaur et al [1] proposed steps which included morphological opening and image subtraction, binarization, edge detection and candidate plate area detection by morphological opening and closing operations. By performing morphological operation using disk as the structural element, the number plate area is enhanced. Because of this enhancement, on converting the image to binary does not cause character of number plate to be disconnected into different components, which helps while edge detection. To detect the candidate area, again morphological operations are performed and connected component analysis is carried out to segment the region of interest.

   Bharat Raju Dandu and Abhinav Chopra et al [3] proposed technique where they used edge detection, smoothening and connected component analysis to minimize the probable areas and segment the number plate.

   Manisha Rathore and Saroj Kumari et al [4] implemented an algorithm where dilation was carried out on image to sharpen the image and connect the broken lines. It was followed by

horizontal and vertical edge processing to minimize the probable areas containg number plate. Among all the areas, the region with maximum horizontal and vertical histogram is identified and extracted.

Mr. G. T. Sutar and Prof. Mr. A.V. Shah et al [5] used area reduction, thresholding and connected component method to localize and segment the number plate. To reduce the probable areas, number of rows(r) and columns(c) were calculated, and the probable area was reduced to (r/3:r, c). After that, thresholding is applied to convert the image to binary. After evaluating the boundary properties, the number plate region is extracted.

Ankush Roy and Debarshi Patanjali Ghoshal et al [7] have used adaptive thresholding, component labelling and region growing to localize the region of number plate. In adaptive thresholding, based on the neighbourhood of the pixel thersholding is carried out. After this, connected component analysis is carried out to detect the area of number plate. This technique can work properly if the number plate is properly illuminated. In conditions where the number plate does not have proper amount of brightness, or contains shadow, adaptive thersholding does not give desired results.

Priyanka Prabhakar, Anupama P and Resmi S R et al [8] have used the concept of sharp variations of intensity in image to detect the region of number plate. Canny edge detection and Hough transform is applied to extract the region of number plate.

Trupti Gondaliya and Prof. Piyush Gohel et al [9] has used edge detection to localize the area of number plate and connected pixel approach to extract the region of interest.

Dr. P. Ramasubramanian, R. Jerlin Emiliya, R. Janaki, B. Gifston Daniel and C.Anand et al [10] have described a unique approach to minimize the probable areas. After performing edge detection on the pre-processed image, to eliminate the non-number plate regions, high-gradient-averaging (HGA) method is applied. Since the number plate has the strongest gradient, using HGA the area of number plate is detected.

Fajas F., Farhan Yousuf, Remya P. R., Adarsh P. Pavanan, Sajan Ambadiyil and Varsha Swaminathan et al [11] have used width by height factor of Indian number plates to the ones present in image to detect the region of number plate.

Prathamesh Kulkarni, Ashish Khatri, Prateek Banga and Kushal Shah et al [12] have used edge detection, adaptive binarization, inverted-L masking and white-pixel, column-wise and row-wise thresholding to minimize the area of number plate. After these different types

of thresholding only the characters of number plate will be white in the image, which can be extracted.

Xiaojun Zhai, Faycal Benssali and Soodamani Ramalingam et al [13] have used morphological operations, thresholding and labelling of components. Moprhological operations such as dilation and erosion to remove the unwanted regions of image and enhance the area of number plate. After this thresholding is performed to binarize the image. Again opening morphological operation is performed to remove the unwanted non-number plate regions. Because of this, some pixels of plate region are also erased, and hence an extra closing operation along with erosion is performed. After this labelling of components is carried out and plate region is extracted by analysis of these labelled components.

V. Swetha and D.R. Sandeep et al [14] have implemented a technique for localization of number plate considering that the background of number plate is yellow. In this case, the entire image is scanned pixel by pixel, if the pixel is yellow, its value is replaced by 1 otherwise 0. After this smearing algorithm is applied to extract the plate region. The basic flaw of this technique is that the background of number plate is yellow in case of taxis only. This technique is specifically used for vehicle classification.

3. Character Segmentation:

Most of the character segmentations method are based on labelling the components or connected component pixel approach as described in [5] [9]. In both these approaches, components are labelled based on their connectivity or neighbourhood. Sahil Shaikh, Bornika Lahiri, Gopi Bhatt and Nirav Raja et al [6] have used 4-connected ad 8-connected approach to segment the characters. Manisha Rathore and Saroj Kumari et al [4] have used smearing algorithms in both horizontal and vertical histogram to segment each character. Priyanka Prabhakar, Anupama P and Resmi S R et al [8] have segmented characters by finding horizontal boundaries between characters. Since characters will be separated by black spaces, detecting such horizontal boundaries can indicate the beginning vertical value of characters. Fajas F., Farhan Yousuf, Remya P. R., Adarsh P. Pavanan, Sajan Ambadiyil and Varsha Swaminathan et al [11] have used color and equidistance between characters to segment characters. Since the characters of number plate will have similar color and font structures, it becomes easy to break apart each individual character using row and column segmentations. However, this technique will work efficiently only if the characters are evenly spaced or have similar font structures.

4. Character Recognition:

The optical character recognition algorithms mostly use template matching [4] [5] [6] [8] [9] [12] [14] [16] [17] or neural networks [7] [11]. In template matching, each character that has been extracted from the number plate is compared with the template sets which comprises of alphabets and numbers. Using statistical correlation method, the template with highest correlation to extracted character is stored as the recognized character. While in neural networks, a two-step process is carried out. The first step includes learning mechanism where the neural network is taught about variations of a single character. Second step includes the recognition mechanism where the extracted character is fed to every node in network, and the recognition occurs based certain constraints [11]. Another alternative to correlation method for template matching is to calculate the matching score of characters extracted from number plate to templates using subsequent algorithmic rule [8]. Feature extraction using Principal Component Analysis (PCA) is another method for OCR [15]. Here PCA is used to build the feature vectors. Along with this, Support Vector Machines (SVMs) can be used [15]. Even though only template matching can be used to perform OCR, preceding it with feature extraction and recognition of pattern can give better results [18].

Chapter 4

Research Methodology

The proposed approach or automatic number plate recognition is described in this section. The input to the system is image of vehicle captured by a digital camera, taken from approximately 2.5-3m. There are 3 different kinds of input images based on the illumination conditions and amount of skew. The output of the system is the recognized number plate. The flow of algorithm can be described as:

1. Image acquisition
2. Skew correction
3. Enhancement of characters of number plate
4. Morphological processing to minimize the probable areas of number plate
5. Locating the area of number plate
6. Extraction of number plate
7. Segmentation of characters
8. Optical character recognition

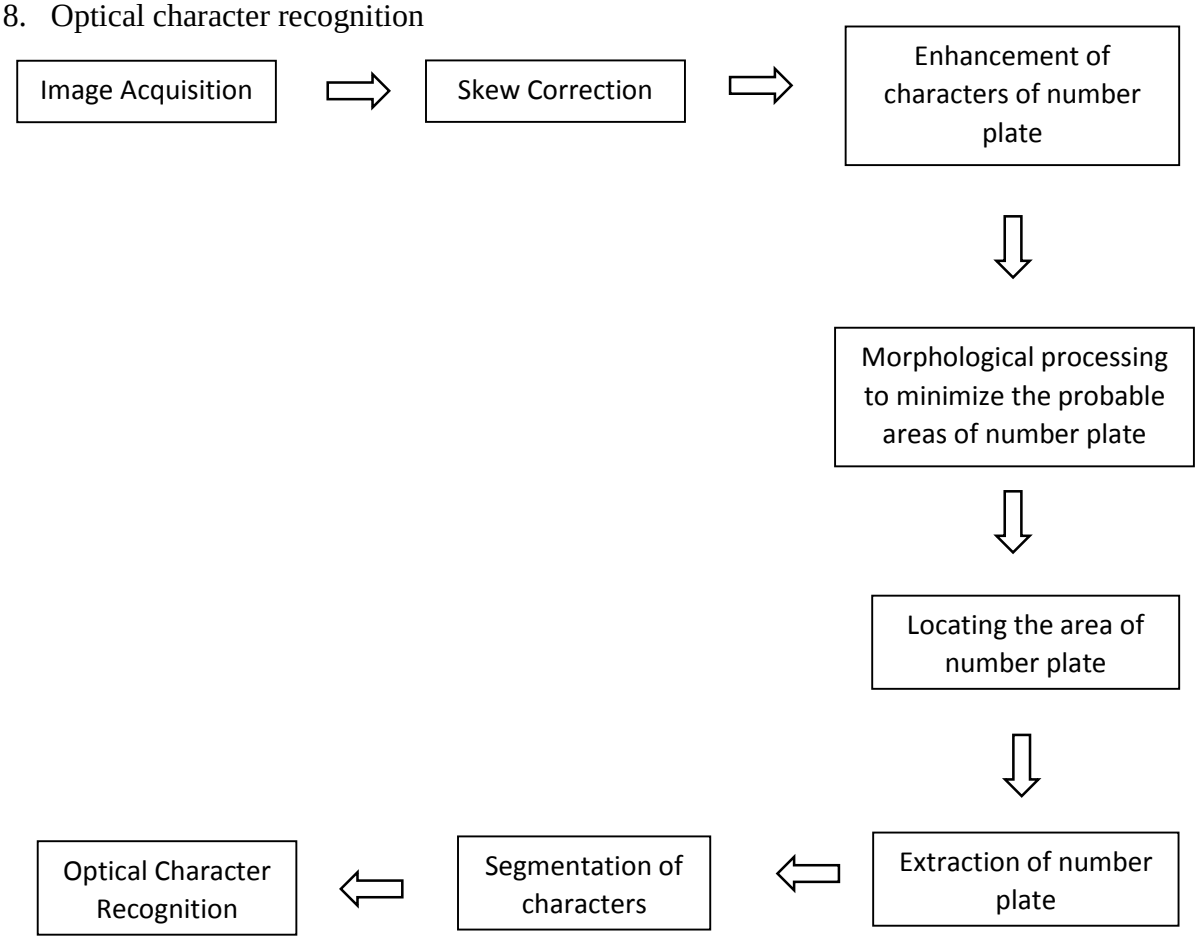


Figure 3: Flow of Proposed Algorithm for ANPR

Skew correction and enhancement of characters are included in pre-processing, morphological processing, locating area of number plate and extraction of number plate are included in localization and extraction of number plate.

The following image is the input image for this section.

Figure 4: Input Image

1. Pre-processing:

   The first step of pre-processing is skew correction. Since it is possible that the image may itself be skewed (because of orientation of camera) or the number plate may be oriented at an angle, it becomes necessary that skew correction be applied, otherwise the accuracy of system suffers. For skew correction, the input image is firstly converted into grayscale and edge detection is performed using Sobel method.

Figure 5: Grayscale processing

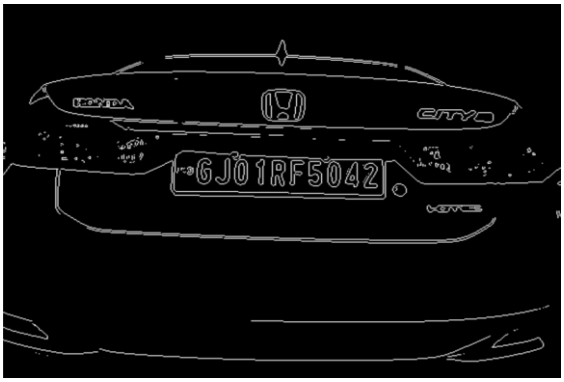


Figure 6: After edge detection

To detect the amount of skew, radon transform is performed. Radon transform is the projection of image intensity along a radial line oriented at specific angle. The angle at which maximum intensity is projected is the skew angle. This angle is subtracted from 90, and image is rotated by the obtained amount.

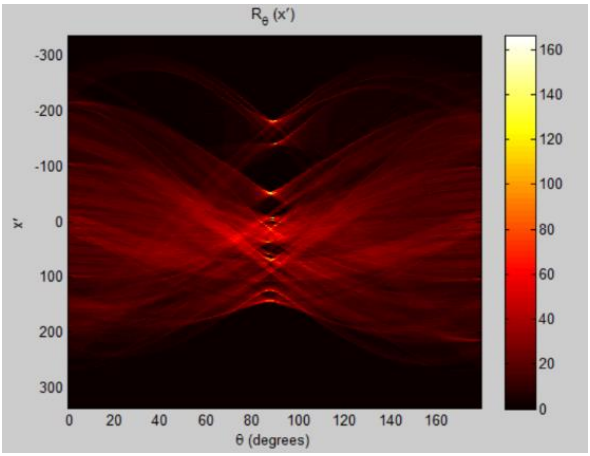


Figure 7: Radon Transform

Figure 8: After skew correction

The second step is enhancement of characters in number plate. For this morphological operators dilation and erosion are used. These dilation and erosion operations are carried out using disk as the structuring element. The output of these two operations are subtracted, and adjustment of intensities is performed to enhance the characters.

Figure 9: Dilation

Figure 10: Erosion

Figure 11: After subtracting dilated image from eroded image

Figure 12: After enhancement of the subtracted image

2. Localization and Extraction of Number Plate:

   For locating the number plate, firstly the probable areas have to be minimized. For this, firstly the holes are filled in the image obtained from step 1. Morphological operation erosion is used with structuring element line to eliminate the horizontal lines. After performing above mentioned steps, most of the large areas except the one containing number plate are eliminated, and hence to eliminate the remaining small regions thresholding is used.

Figure 13: After filling the holes

Figure 14: After performing erosion with line (0˚) as the structuring element

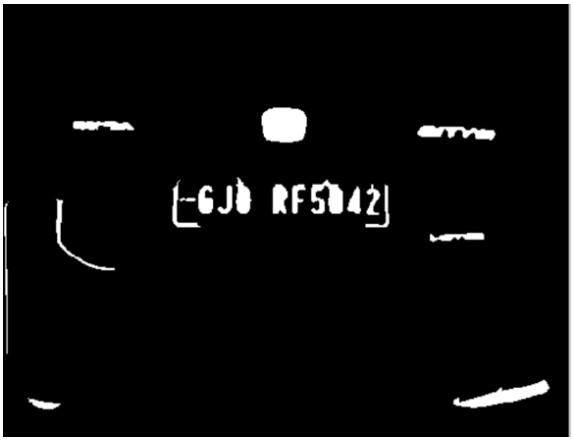


Figure 15: Eliminating region below specific threshold

Now, boundary properties is used to locate the region of number plate. Since all the characters of the number plate are written with same font size (most of the number plates have same font size) and have same alignment (of rows), using boundary properties, we can locate all those regions that have almost same height and width. Also since the alignments of characters are in same direction, the beginning row value of all characters must be same, +/- 5 pixels. Using these properties, characters of number plate are located, and hence in general the number plate region.

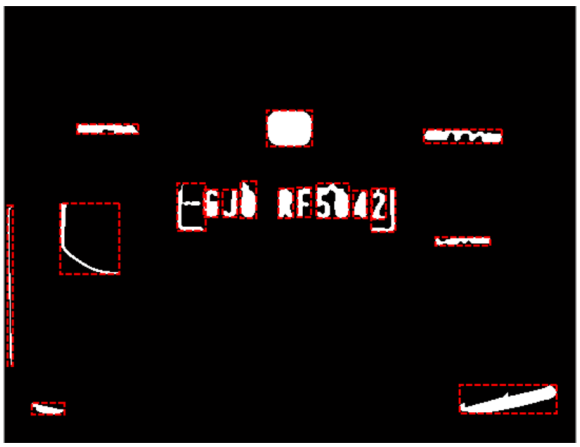


Figure 16: Connected components in the image

Figure 17: Number Plate detected

Using cropping method, the located region of number plate is extracted.

Figure 18: Segmented Number Plate

3. Character Segmentation:

To extract each characters properly, it is necessary that the characters are not disjoint into parts or have extraneous regions attached to them. Also, it is possible that some characters remain black upon converting to binary because of poor illumination conditions. To enhance such plates, adaptive histogram equalization can be used. In conditions of poor illumination, the histogram is skewed towards left, and hence enhancement using histogram equalization can be done. A condition, whether the histogram of number plate is skewed towards left is checked every time number plate is segmented. If it returns true, then equalization is performed else nothing is done. This gives better results during character segmentation and OCR. After this, binarization of the segmented number plate is performed. Here, for the segmented number plate, the histogram (Figure 19) is not skewed towards left, and hence histogram equalization is not performed.

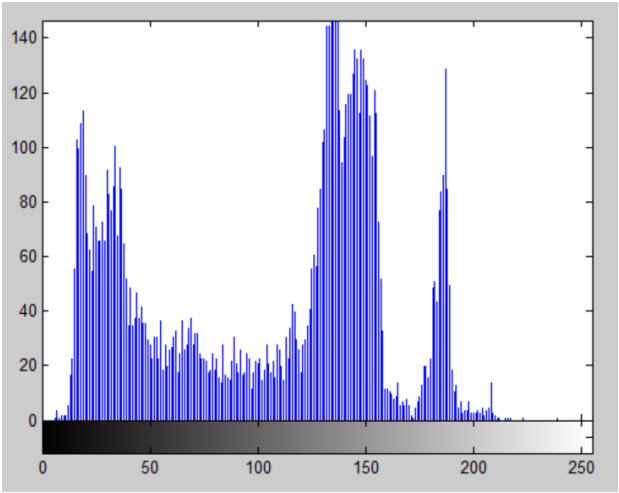


Figure 19: Histogram of segmented number plate

Figure 20: Binarization of number plate

Next, labelling of all regions is performed. Since each region will have a unique label, its properties like height (number of rows) and width (number of columns) can be extracted. Using these properties, the characters can be distinguished from extraneous regions, if they are present. These regions can then be extracted and stored in structures for further processing.

Figure 21: After labelling each connected component

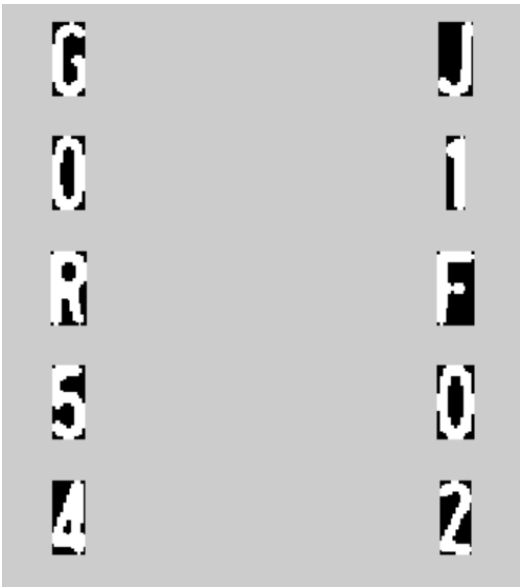


Figure 22: Segmented characters

Here it can be seen that even if the segmented number plate contains extraneous regions, it does not affect the character segmentation algorithm.

4. Character Recognition:

Optical Character Recognition is performed using template matching method. Here, statistical correlation is used to compare the extracted character regions with the templates. The template sets consists of images of alphabets and digits, with each image of fixed dimensions and having black background with alphabets or digits in white. The segmented characters are compared to all the templates, and the template with which the segmented region shows highest correlation is considered as the output.

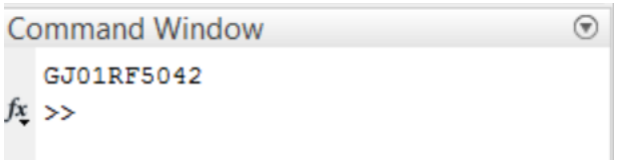


Figure 23: OCR

Since most of the vehicles follow the standard license number format, as described in introduction, the total number of characters in most of the plates are 10. In such situation, the OCR algorithm can be implemented based on the position of segmented characters. Since the first two characters (state codes) will always be alphabets, the segmented characters will only be checked with alphabet templates. Similarly rest of the segmented regions will be checked.

Also, it is possible that wrong state codes can be predicted because some characters have similar resemblance to others, for example ‘D’ and ‘O’, ‘B’ and ‘8’ or ‘G’ and ‘O’. Because of this, the accuracy of system decreases. Validation for first two characters can be done easily since they are state codes. In this case, the predicted characters are matched with the legal state codes, and if a match does not exist, the algorithm for these two characters can be executed again. But if there is an error in any other positions, no validation can be performed. In this case, using extra templates for ambiguous characters, for example using more than one template for ‘O’ or ‘D’ or ‘8’, can be used to increase the accuracy.

Figure 24: Input image

Figure 25: Segmented number plate (binary form)

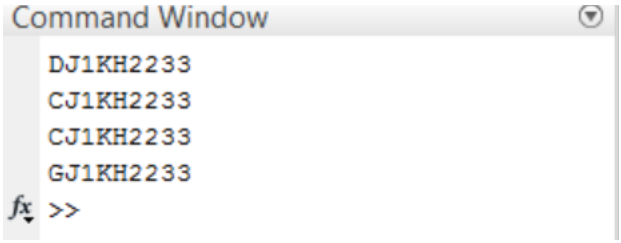


Figure 26: OCR validation

As shown in above images, the state code is not recognized properly. But after applying the validation for state code, after 4 rounds of OCR, correct results are obtained.

Chapter 5

Implementation Details & Results

MATLAB R2014a is used to implement the ANPR system. The input images are divided into 3 sets, based on the illumination conditions and the amount of skew present. These sets are

1) Images which have proper illumination conditions and have little amount of skew
2) Images which have poor illumination conditions and might contain shadows on number plate, and have little amount of skew
3) Images having varying amount of skew angle

The images have been captured from digital camera at a distance of 2.5-3.5 m from the vehicle, and have the following properties:

Colorcode – RGB
Format – jpg
Size – 921 KB to 2.3 MB
Resolution – 72 dpi
Dimensions – 2981 x 1706 to 3264 x 2448
Bit depth - 24

The results of an image from each set is shown below. Results are shown after each major operation.

SET 1:

Set 1 contains images which have proper illumination conditions and have less amount of skew angle present in the image. Figure 4 is part of set 1, and hence its results are as shown in Section 4.

SET 2:

Set 2 contains images which have poor illumination conditions, may contain shadow(s) on number plate and have less amount of skew angle present in the image.

Figure 27: Input image from Set 2

Figure 28: Grayscale conversion

Figure 29: Edge detection

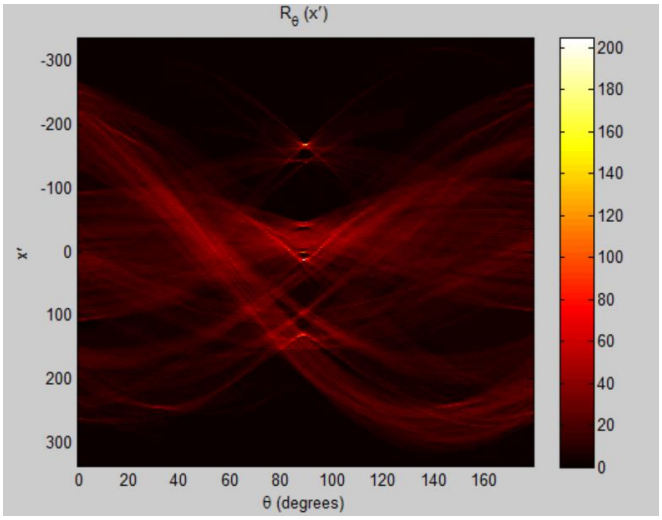


Figure 30: Radon Transform

Since the maximum intensity is at 0˚ angle, there will be no rotation of the image as shown in Figure 31.

Figure 31: After skew correction

Figure 32: Subtraction of dilated image from eroded image

Figure 33: After enhancement on image obtained from erosion operation using line (0˚) as structuring element

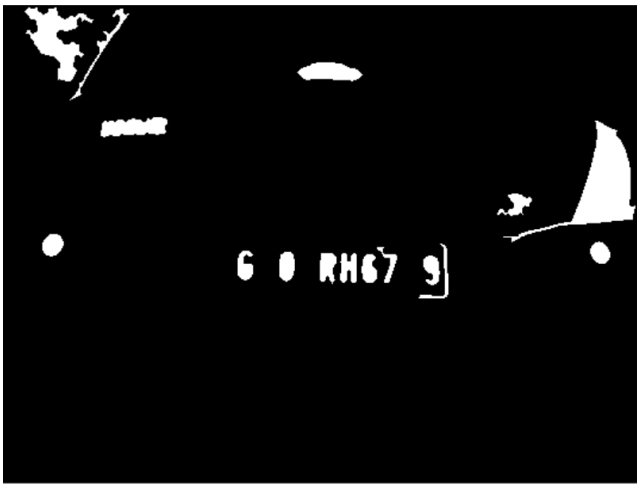


Figure 34: Filling holes and elimination of regions below threshold

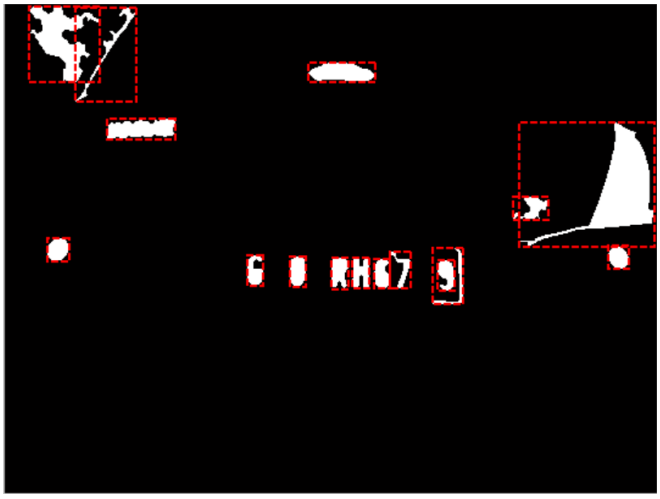


Figure 35: Connected components

Figure 36: Number plate detected

Figure 37: Segmented number plate

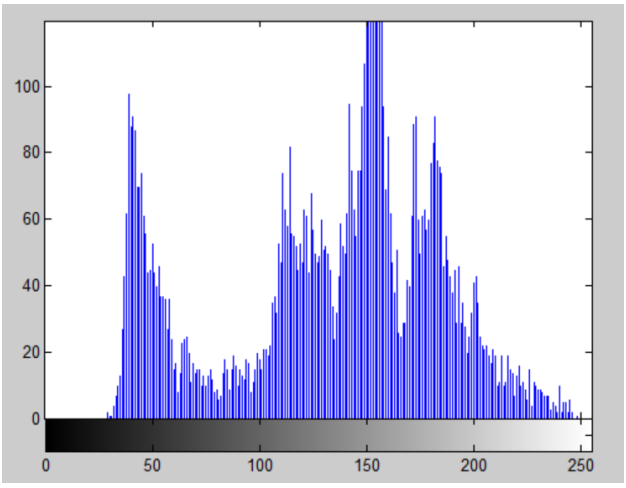


Figure 38: Histogram of segmented number plate

Figure 39: Binarization of segmented plate

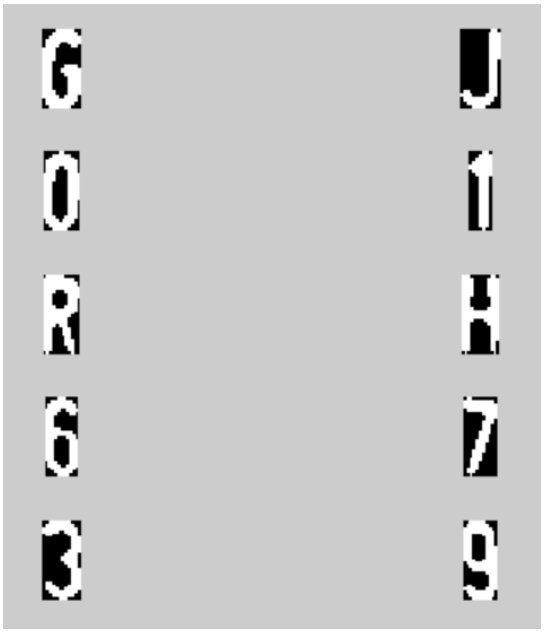


Figure 40: Segmented characters

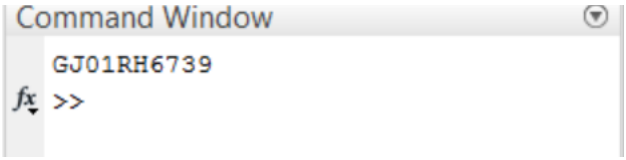


Figure 41: OCR

Hence it can be seen that even though the image contains numerous shadows, the number plate is detected, extracted and recognized successfully.

SET 3:

Set 3 contains images with varying amount of skew. These images also have varying illumination conditions.

Figure 42: Input image from Set 3

Figure 43: Grayscale processing

Figure 44: Edge detection

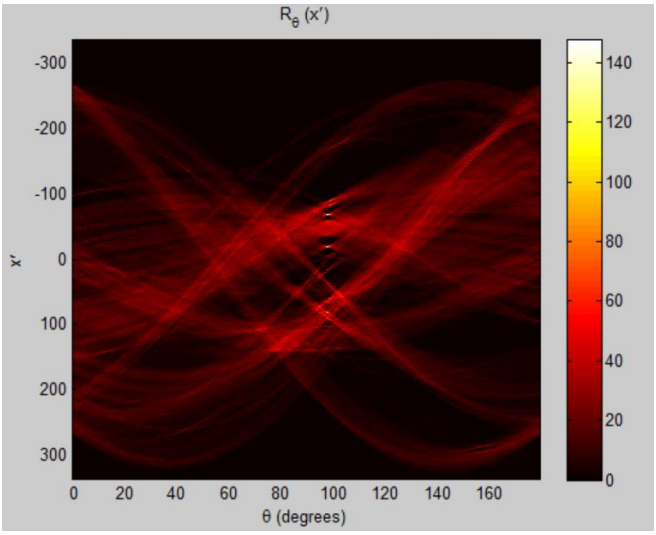


Figure 45: Radon Transform

Figure 46: Skew correction

Figure 47: Subtraction of dilated image from eroded image

Figure 48: After enhancement on image obtained from erosion operation using line (0˚) as structuring element

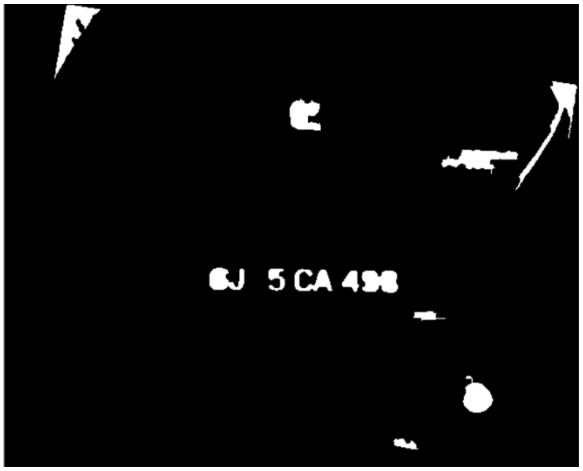


Figure 49: Filling holes and elimination of regions below threshold

Figure 50: Connected components

Figure 51: Number plate detected

Figure 52: Segmented number plate

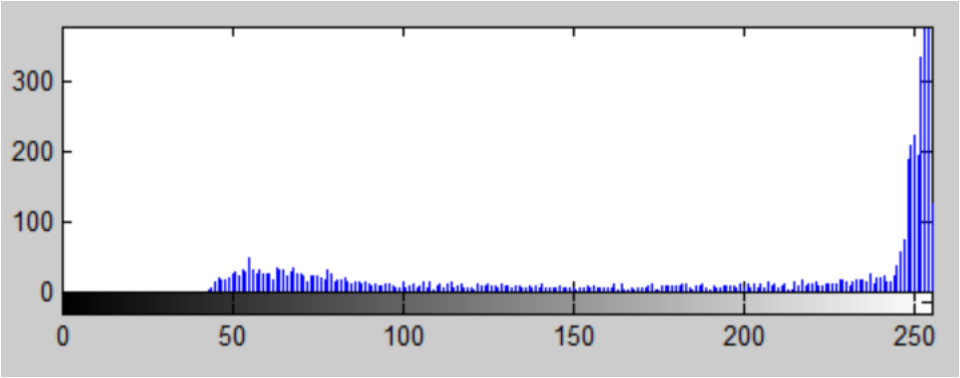


Figure 53: Histogram of segmented number plate

Figure 54: Binarization of number plate (without applying histogram equalization)

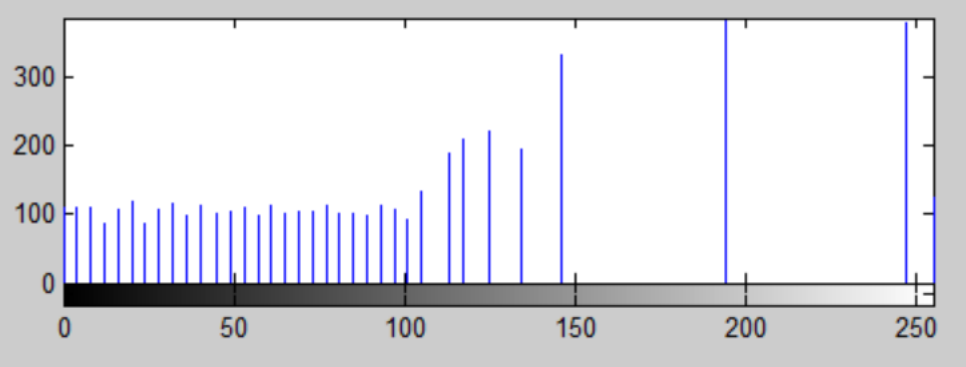


Figure 55: Histogram after applying equalization

Figure 56: Binarization of number plate (after applying histogram equalization)

Figures 53, 54, 55 and 56 show that without applying histogram equalization, the binarization of segmented number plate will be as shown if Figure 54, which has very little details to segment characters properly. And as a result of this, OCR algorithm will not work properly. But because histogram equalization applied on left-skewed histogram, the binarization gives proper results.

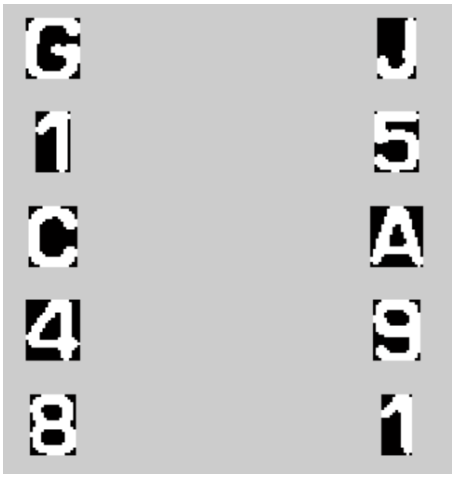


Figure 57: Character segmentation

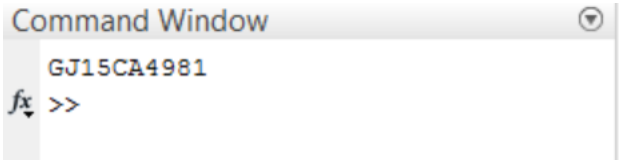


Figure 58: OCR

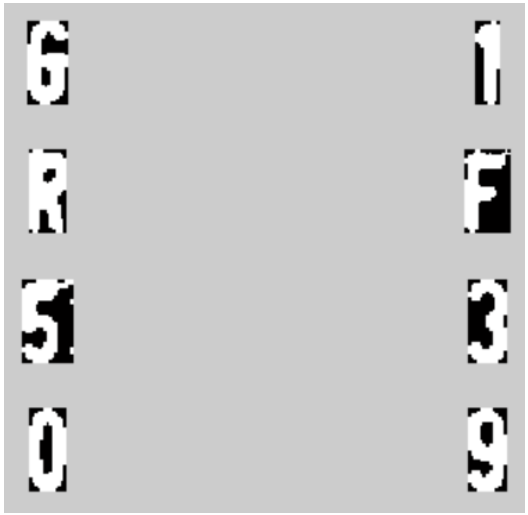
Chapter 6

Result Analysis

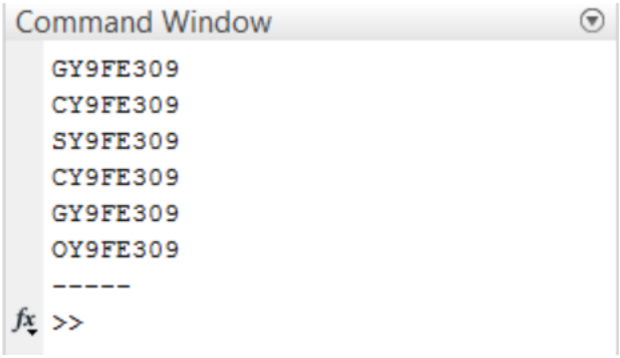
In Localization and Extraction of number plate step, after eliminating regions below threshold, some of the characters of number plate are also eliminated, but this does not pose a problem until only 1-2 characters of the plate are present. This is because the algorithm searches for components that lie in same line, +/- 5 pixels, and hence even if some of the characters are eliminated, the segmentation of entire number plate is carried out as shown in Section 5. The only problem that causes erroneous output during Character Segmentation and Character Recognition is when due to poor illumination on number plate or extraneous objects like (bolts or screws) present around characters, number plate is not segmented properly. This is because either the characters merge with extraneous objects or are not detected because of poor illumination.

(a)

(b)



(c)

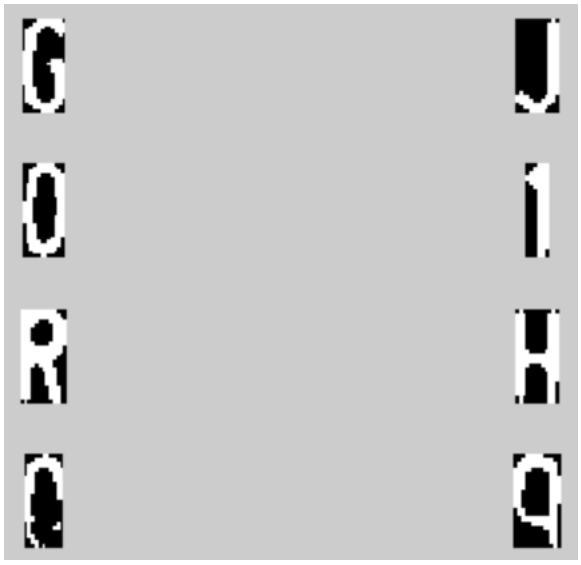


(d)

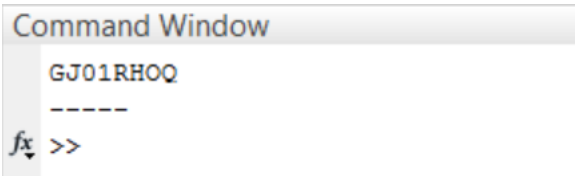
Figure 59: Erroneous OCR because of extra components attached to characters (a) Input Image (b) Segmented and Binarized number plate which contains extraneous regions connected to characters (c) Character segmentation (d) Erroneous OCR

(a)

(b)



(c)



(d)

Figure 60: Erroneous OCR because of some characters not being detected (a) Input Image (b) Segmented and Binarized number plate with '0', '7' and '9' not being detected properly (c) Character segmentation (d) Erroneous OCR

In Character Segmentation step, the condition which checks whether the histogram of segmented number plate is left-skewed and perform histogram equalization if it returns true, has provided with better and accurate results. Table 1 shows this comparison. Each set contains 50 images.

	Positive Results		
	Without condition for histogram equalization	**Without condition for histogram equalization**	**Increase in accuracy (%)**
Set 1	38	45	18.4
Set 2	35	40	14.3
Set 3	37	45	21.6

Table 1: Comparison of results before and after applying histogram equalization

In Character Recognition step, standard template matching contains templates of 26 alphabets and 10 digits, which results in poor recognition because of ambiguous characters like ‘D’ and ‘O’ or ‘8’ and ‘B’. Since it is not necessary that the fonts of number plates are similar to the ones used as templates, recognition might not give proper results. And hence, to increase the accuracy of OCR, extra templates (31 alphabets + 17 digits) of same characters having different fonts are created and used. Also, validation of the first two characters which are the state codes is performed. Table 2 shows the comparison for OCR with standard templates and OCR using standard and extra templates along with state code validation. Each set contains 50 images.

	Positive Results		
	OCR using standard templates	**OCR using standard + extra templates along with state code validation**	**Increase in accuracy (%)**
Set 1	32	37	15.6
Set 2	27	32	18.5
Set 3	30	35	16.7

Table 2: Comparison of results for OCR with standard templates and OCR using standard and extra templates along with state code validation

Chapter 7

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