Heuristics for license plate localization and hardware implementation of Automatic License Plate Recognition (ALPR) system

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Heuristics for license plate localization and hardware implementation of Automatic License Plate Recognition (ALPR) system

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May 12, 2012

Certificate

This is to certify that the project entitled '**Heuristics for license plate localization and hardware implementation of Automatic License Plate Recognition (ALPR) system**' submitted by **Sandeep Singh Chhabada(108CS023)** is an authentic work carried out by them under my supervision and guidance for the partial fulfillment of the requirements for the award of **Bachelor of Technology Degree** in **Computer Science and Engineering** at **National Institute of Technology Rourkela.**

To the best of my knowledge, the matter embodied in the project has not been submitted to any other University / Institute for the award of any Degree or Diploma.

Date – 12/05/2012 **Prof. Dr. Banshidhar Majhi**

Rourkela (National Institute of Technology Rourkela)

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Abstract

The project "Heuristics for license plate localization and hardware implementation of Automatic License Plate Recognition (ALPR) system" deals with detection and recognition of license plate from a captured front view of any car. The work follows all the steps in an ALPR system like preprocessing, segmentation, and license plate identification, extraction of individual characters and finally recognition of each character to form a string to match with the registered License plate numbers. The main contribution in the work is to expedite the number plate isolation from a set of segmented candidates. It utilizes a set of heuristics typically transition from object to background and vice-versa, aspect ratio of the bounding boxes. This narrow down the number of candidates for further processing and further, we suggest a rank based identification of each character in the number plate. The process scheme along with the existing methodologies is integrated to develop the overall ALPR system. A set of standard images collected from internet as well as self-collected car images of staff vehicles are used for simulation. The experiments are conducted using OpenCV. For validation, a working ALPR hardware prototype is developed using AVR development board (ATmega32 microcontroller), GP2D120 distance measurement sensor (IR-sensor). Interfacing between PC and controller-board is done using serial port. The model works with an accuracy of 80%. The ALPR system has a further scope to improve the recognition speed using parallel processing of various sub-steps.

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Chapter-1

Introduction

1. Introduction

A license plate is the unique identification of a vehicle. The basic issues in real-time license plate recognition are the accuracy and the recognition speed. License Plate Recognition (LPR) has been applied in numerous applications such as automatically identifying vehicles in parking slots, access control in a restricted area and detecting and verifying stolen vehicles. Till now, there have been some well-known commercially operational LPR systems around the world. It is assumed that these systems work under some given constraints and the cameras are mounted at fixed locations without mobility. LPR systems consist of three major components: license plate detection, character extraction and character recognition.

License Plate detection is the first important stage of an LPR system. Quality of algorithms used in a license plate detector determines the speed and accuracy of the license plate detection. In this paper the distance between the camera and the car is kept approximately constant. For license plate detection purpose the concept of edge detection [5,9], contour determination and bounding box formation and elimination is used. Selection of license plate areas (LPA) and their elimination to obtain the actual license plate was based on various heuristics. This stage is important since improper detection of LPA can lead to misrecognized characters.

Character Extraction or character segmentation is the second component of our LPR system. It takes a properly segmented license plate as an input. Some preprocessing is done on the license plate image for the removal of noise. Various morphological operators are used on the image for this purpose and the noise free output image is sent for character segmentation. Image binarization and image projections are used for character extraction.

In this project work we have developed a full-fledged Automatic License Plate Recognition (ALPR) system with hardware implementation. Including the main steps we have suggested heuristics to identify the number plate faster than the existing scheme. Further, Character recognition has been done using template matching and license plate are authenticated using rank based search strategy.

Chapter-2

Literature Review

2. Literature review

Extensive research has been done in the area of License Plate Recognition since its invention in the year 1976 at the Police Scientific Development Branch in the UK. This is a topic of recent research attracting several papers around the world. Here we mention some of the relevant works in this section. Any basic ALPR system has 3 fundamental problems.

(i) License plate detection,

(ii) Character Segmentation and

(iii) Character Recognition.

The basic steps are described below.

2.1 License Plate Detection Approaches

Some important concepts relevant to the LP detection approaches are mentioned. Processing of boundary lines, from a gradient filter, and an edge image is discussed [10]. This edge image is threshold and then processed with Hough Transform (HT), to detect lines. Eventually, couples of two parallel lines were considered as plate-candidates. However, boundary line detection is not suitable in the case of not finding horizontal pairs. It may also happen that the image boundary line may be absent or not detected properly due to noise and uneven brightness. Furthermore, HT is inherently a heavy computation task. The color and textures of the LP have also been used to identify it [11], but they seem to be ineffective, especially when the system has plates of different colors and sign patterns. Other common approaches involved are Top Hat and Bottom Hat filtering (highlights the black-white transitions) [12] and Binary Morphology algorithm (like Otsu's method) [13]. But all these algorithms rely on color information and special signs.

2.2 Character Segmentation Approaches

There are many common algorithms for Character Segmentation such as direct segmentation [14], projection and cluster analysis [15] and template matching [16]. In direct segmentation characters are segmented directly based on the width of the characters and spaces between them. This algorithm is fast but the boundaries of the character region must be located accurately. In Projection and Cluster Analysis the number of white pixels in each vertical column is counted and recorded. The character regions have more white pixels as compared to the region between them. By detecting the trough of white pixels between characters the spaces can be located. In template matching algorithm, a template is used to scan the image and find the maximum difference value of white pixels between the region of characters and the region between the characters. Other approaches for segmentation includes segmentation through region growing approach and the most common one is segmentation using vertical and horizontal image histogram methods. The region growing method takes quite much of the computation time so histogram method is mostly used which is very fast and its accuracy is also considerable.

2.3 Character Recognition approaches

The basic two approaches for the character recognition is

1.) Feature matching approach.
2.) Template matching approach.

The first approach is the machine learning approach and is the most commonly and widely used approach for the recognition process. This method requires having a large database of test images on which the system is trained to give specific output. The training process takes much time and it depends on the varieties of the sample images taken for the training purpose. This method takes much time to evaluate but the accuracy of recognition is very high.

The second method, template matching method basically measures the linear relationship between the captured images and the database images. This method totally relies on the quality of the captured image. The captured image is compared with all the database images of alphanumeric characters and then the most promising character is chosen. This way the recognition process is done. This method is quite faster than the feature matching approach but we have to compromise with the accuracy of recognition. So, the basic difference between Template matching and Machine Learning approach is that Template matching is a Shape-Matching approach but machine learning approach is a Feature-Matching approach. So, the time required to train any system for feature matching approach is quite long.

In this project, we have assumed a controlled scenario; template matching approach is used to reduce the total computation for the ALPR system.

2.4. Challenges in ALPR System

The attributes of the License plates play important role in the recognition process. If the size, color and the characters' height and width is pre-defined then the recognition process will be much easier. There are several countries in the world who have adapted this very method of standardizing the License plate. But in India, the license plate is purely localized and even they have different scripts for the characters. So, the recognition process is quite difficult.

Other than this, there are several other parameters on which the quality of the recognition depends. Mostly all the available ALPR systems have certain constraints on them and they benefit from these controlled scenarios.

These constraints are

1. Lack of background objects. – i.e. the image captured by the camera doesn't have much background details.
2. High quality imaging – the quality of the captured image is high, so that it will be easy to evaluate the attributes of the image.
3. Minimal skewing and rotation – the camera is fit such that the captured image will not suffer much decent angle of skewing and rotation.
4. Better Flash – as the License plate is retro- reflective in nature, so if high illumination will be there, then the LP region will be much more brightened and the attributes of the license plate will not be much clearer.

Apart from these conditions, the algorithms applied for the recognition also plays a vital role. If the quality of the algorithm is good, then more varieties of images can be input to the system. And this will reduce the computation speed of the process also.

The most basic issues in the real-time ALPR system is the accuracy and the recognition speed. If we want to have higher accuracy then, the system will take much time.

But if we are working in a controlled scenario, then we can compromise with the accuracy because the quality of the captured image is good. This way we can reduce the computation time.Below are some problematic captured images of the license plate.

The source for the below images is http://www.platerecognition.info/1102.htm.

 Low spatial resolution	 Blurred image	 Low contrast Image
 Over exposed image	 Poor lighting condition (shadow)	 Distorted image

Chapter-3

Proposed Algorithm

3. Proposed Algorithm

In this section I describe my approach where I take up direct techniques from the essential image processing to obtain the candidate areas and subsequently apply domain heuristics to obtain the LPR. The steps followed in LPR system are:

3.1 License Plate Detection

In this stage the license plate region from the given image is located and isolated. Quality of the image plays an important part hence prior to this stage preprocessing of the image is necessary. Preprocessing of the image includes conversion of the colored image into gray scale followed by histogram equalization which enhances the contrast of the image. Below is the original car image (RGB) and its gray scale image.

Figure 1- Input RGB image for Car-1

Figure 2- Input RGB image for Car-2

Figure 3- Gray scale image for Car-1

Figure 4- Gray scale image for Car-1

After this stage the primary process of license plate extraction is carried out.

3.1.1 Edge Detection

Edges are the areas in the image where strong intensity variation is observed while moving from one pixel to another. Detection of the edges helps in reducing the amount of data and filters insignificant data while preserving the important structural property of the image.

There are several ways of detecting edges in an image. The two basic methods used for finding edges are the Gradient method and Laplacian method. Gradient method finds the maximum and minimum of the derivative of the intensity function to detect edges whereas Laplacian method finds the zero point in the crossing of the second derivative function.

The proposed method for finding edges in the car image is Canny Edge detection. This method basically follows the gradient method.

Here the first derivatives is computed in x and y and then combined into four directional derivatives. The points where these directional derivatives are maxima form the candidates which assemble into edges.

However, the most significant new dimension to the Canny algorithm is that it tries to assemble the individual edge candidate pixels into contours as we need contours to find License plate area. These contours are formed by applying a hysteresis threshold to the pixels.

This means that there are two thresholds, an upper and a lower. If a pixel has a gradient larger than the upper threshold, then it is accepted as an edge pixel; if a pixel is below the lower threshold, it is rejected.

If the pixel's gradient is between the thresholds, then it will be accepted only if it is connected to a pixel that is above the high threshold.

The masking method is used for the edge detection which masks the whole image and using different operators, it finds the edges in the image.

The edges are detected using the first derivative of the image space function. The basic formula for this is

$$G = \sqrt{G_x^2 + G_y^2}$$

$$\Theta = \arctan(\frac{G_y}{G_x})$$

Where G_x = Gradient in the x-direction and G_y = Gradient in the y-direction.

The edge direction angle is rounded off to detect only four types of edges. And these are vertical, horizontal and the two diagonal edges.

i.e. Θ is restricted to 0, 45, 90, 135 degrees.

To restrict our application to license plate detection, we need to find only vertical and horizontal and vertical edges in the images. Through this, we are ignoring certain contours which can create problems in further stages.

The result of the canny edge detection on the gray scale images are shown below:

Figure 5 – Canny edge Image of Car-1

Figure 6 – Canny edge Image of Car-2

3.1.2 <u>Contour Detection</u>

Now, the Canny Edge image is sent for contour finding and these contours are stored in a sequence. They are approximated to quadrilaterals because generally License plates are rectangular in shape. In order to speed up the process, the concept of bounding boxes is used. Bounding boxes are rectangles with minimum area required to close in the contours. The result obtained, contain a number of candidate bounding boxes for the license plate and these were eliminated to obtain the actual license plate using various heuristics which are enlisted below:

a) Generally a license plate is a quadrilateral hence the bounding box must have 4 edges.

b) Aspect Ratio: The aspect ratio of the license plate image must lie in the range of 3 to 6.

c) Contrast present in the bounding box: The license plate contains dark colored numbers on a lighter background or vice versa hence a line passing through the middle must show the highest number of fluctuations in intensity as compared to other candidate bounding boxes.

d) After working on a large sample space of images, we observed that the license plate in a car image lies in the lower half, hence only those bounding boxes are selected which fall in lower half zone. The concept used for this heuristics is that the ratio of x co-ordinate of the bounding box to the height of the whole car image should be greater than 0.5.

Images that are shown in Figs. 7 and 8 show possible bounding boxes before and after the heuristics are applied.

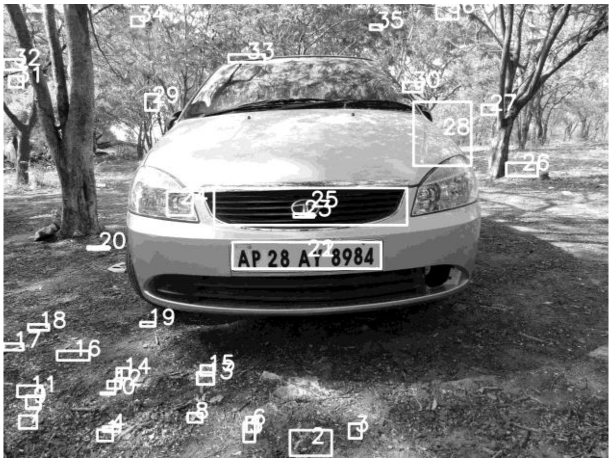


Figure 7- Image showing all possible bounding boxes for Car-1 **Figure 8- bounding boxes after applying Heuristics for Car-1**

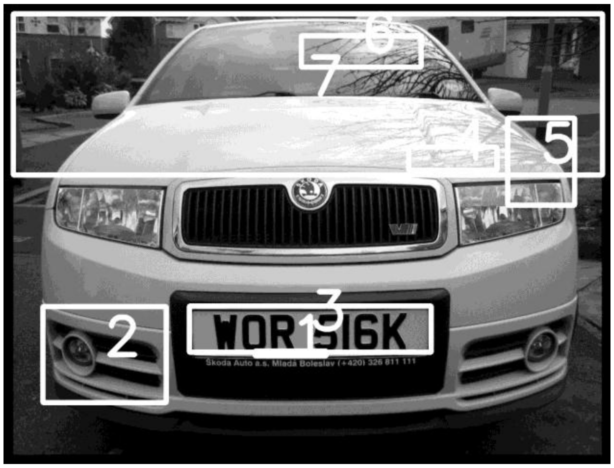


Figure 9- Image showing all possible bounding boxes for Car-2 **Figure 10- bounding boxes after applying Heuristics for Car-2**

From the above figures, it is quite clear that search of LP region narrows down rapidly after using the heuristics mentioned above.

After this process, the optimal bounding box is cropped and extracted from the car image for further processing of character segmentation. The cropping of the bounding box is done using the method of Region of Interest (ROI).

3.2 Character Extraction or Segmentation

The next step is Character Segmentation from the License Plate. This step is preceded by some preprocessing of the license plate image which is necessary for the removal of noise and boundaries. Morphological operations [5] like erosion and dilation are applied on the LP image. Dilation causes the bright pixels within a region to grow and erosion is the converse operation. Dilation tends to smooth concavities and erosion tends to smooth away protrusions in the image which enhances its quality and makes it noise free. After this step the output image is threshold to enhance the numerals and characters in the image, characters being light shaded like white over a darker background like black.

Now character segmentation is carried out and the approach used is Vertical Image Projection [6, 8]. Boundaries from the noise-free license plate image are removed before applying vertical projection histogram in order to threshold the histogram bin value to zero. The coordinates where the histogram bin value is zero are stored. These coordinates form the boundary of each character in the license plate image. They are cropped subsequently using the concept of ROI (Region of Interest) [2].

Images shown below are the result after applying morphological operations on the extracted LP image.

Figure 11- Extracted LP image before preprocessing of Car-1

Figure 12- Extracted LP image after preprocessing of Car-1

Figure 13 -Extracted LP image before preprocessing of Car-2

Figure 14 –Extracted LP image after preprocessing of Car-2

In the above images light colored characters are present on a darker background. Initial application of dilation causes the noise to fade up and characters to get thin. Later, application of erosion affects only the character part of the image and widens them to their original size. This consecutive process of dilation and erosion causes only the noise to get removed. Removing the borders from the LP image helps in the formation of Vertical Image Projection (VIP) histogram. As VIP counts the number of bright pixels for each column of the LP image, if the image contains borders then totally dark column will also make some positive bin value for the histogram. This may create problem in segmenting the characters from the image. Hence removal of borders causes the threshold bin value to be zero.

The results of the vertical image projection histogram on both the car images are shown in the next page.

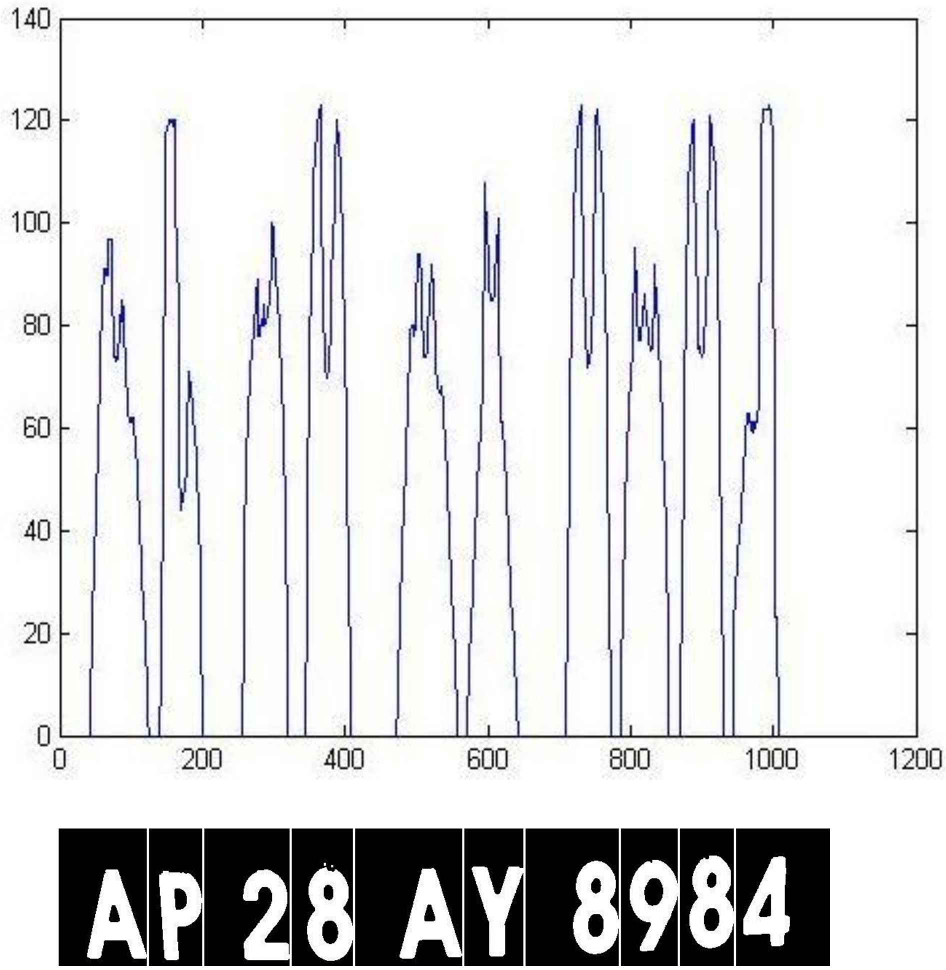


Figure 15- Vertical Image Projection Histogram image for Ca-1

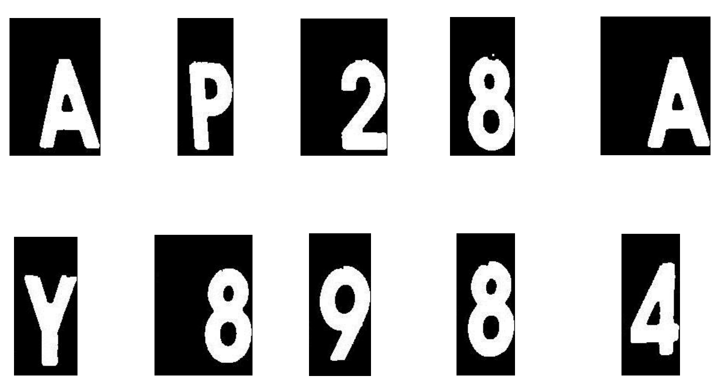


Figure 16- Segmented and cropped characters

From the LP image for Car-1

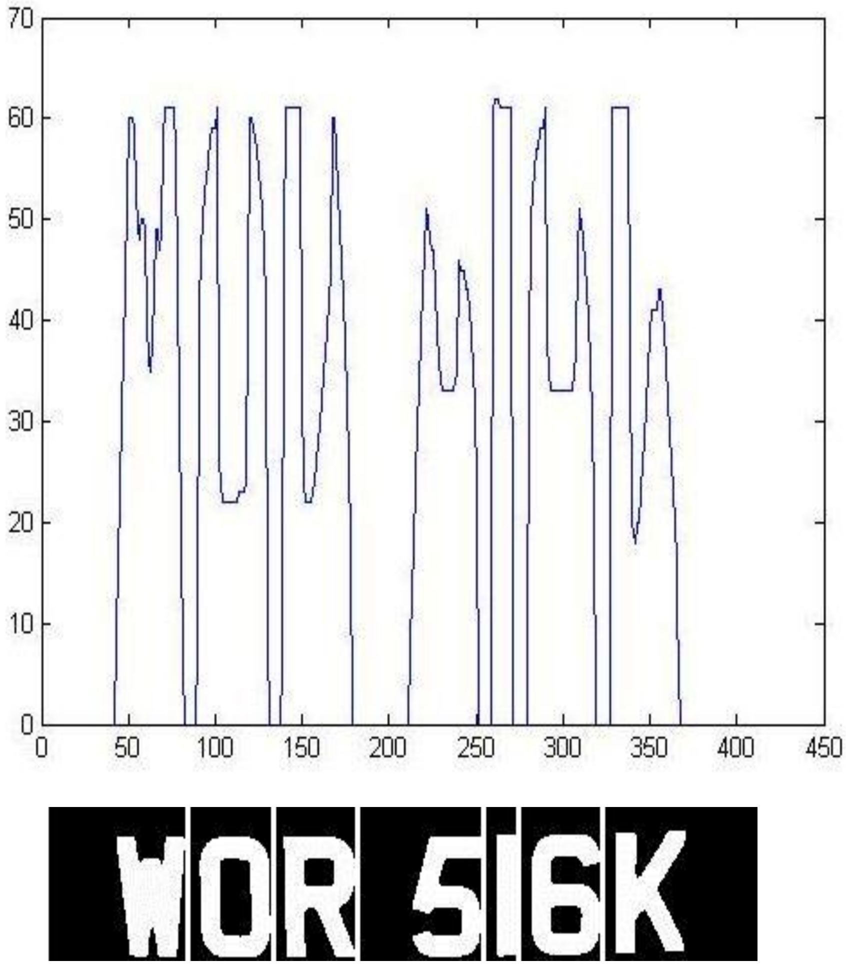


Figure 17- Vertical Image Projection Histogram image for Car-2

Figure 18- Segmented and cropped characters

From the LP image for Car-2

3.3 Character Recognition

The approach followed for this purpose is the Template Matching approach. This method basically matches the linear relationship between the detected character image and the standard database images of characters. The concept of correlation co-efficient is used for template matching. The correlation coefficient is a measure of the strength of the straight-line or linear relationship between two variables. The correlation coefficient takes on values ranging between 0 and 1. Formula for the computation of correlation co-efficient is

$$\frac{\sum_{m}\sum_{n}(A_{mn}-\overline{A})(B_{mn}-\overline{B})}{\sqrt{\sum_{m}\sum_{n}(A_{mn}-\overline{A})^{2}(B_{mn}-\overline{B})^{2}}}$$

Where A and B are matrices of same size and A-bar = mean2(A) & B-bar = mean2(B).

The standard database seize for the character images are chosen as 71X74. All the detected character images are first scaled to 71X74 size then their matching is done with the database image.

The searching for the vehicle number from the database follows a rank-based approach. Here the recognised characters are stored in rank-based manner i.e. for this project, I took first 8 most promising characters (recognised) for each detected letter image.

In which first 4 characters are aplhabets and the rest 4 are numbers. This dixtinction is done basically to reduce the recognition of alphabets instead of numbers and vice-versa. So that both numbers and alphabets have equal chances of occurance in the license plate.

The result of the recognition for car-1 image is

- The recognized characters for LP-1 image (AP28AY8984) is

A	I	X	K	4	1	3	6	→ A
P	F	R	B	9	7	8	2	→ P
Z	G	B	S	**2**	7	9	1	→ 2
S	B	G	C	**8**	6	0	9	→ 8
A	X	I	W	4	1	3	2	→ A
Y	V	T	I	7	1	3	2	→ Y
S	B	G	C	**8**	0	6	9	→ 8
P	V	Q	O	**9**	0	5	6	→ 9
S	B	G	C	**8**	0	6	9	→ 8
J	X	W	A	**4**	2	8	9	→ 4

The above data shows that , the very first recognised characters are matched appropiately.

The 8 elements in each row shows in the first best 8 promising characters with which the detected image can be approximated with. So it is basically a Ranking-Based method of recognising.This type of search helps if the very first recognised character is not the correct one, then it may look for the remaining 7 characters in the database numbers (which has list of valid License Plate Numbers).

The result of the recognition for car-2 image is

- The recognized characters for LP-2 image (WOR5I6K) is

V	**W**	X	Y	4	8	7	9	→ W
D	**O**	B	G	0	8	6	9	→ O
R	P	F	B	9	8	0	6	→ R
B	S	G	F	8	6	**5**	9	→ 5
M	**I**	S	X	8	2	9	3	→ I
B	G	S	E	8	**6**	0	5	→ 6
K	X	R	L	6	3	8	5	→ K

Here, not all characters are matched at the very first comparison. So if the database for valid license plate has number like WOR(6)I6k instead of WOR(5)I6k, then it can create problem for the authentication. But this searching process ensures that if WOR5I6k number is there in the database file , then it will surely match it.

Chapter-4

Hardware Implementation of ALPR system and Results

4.1. Block Diagram of proposed ALPR system

The block diagram for the LPR system is shown below.

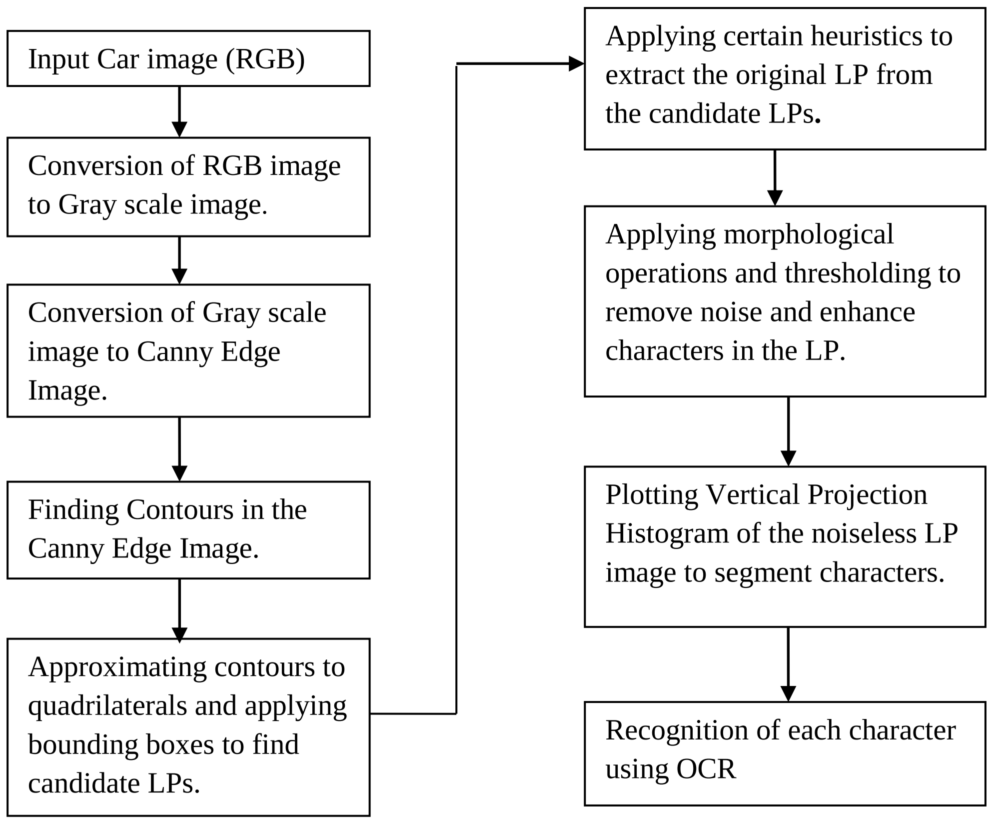


Figure 19 – Block Diagram of proposed LPR system

4.2 Hardware Requirements

The hardware part required for building the ALPR system is

1.) AVR 40 pin rapid Robot Controller Board.

2.) Sharp GP2D120 Distance Measurement Sensor.

3.) LCD screen (to show different messages).

4.) Serial port connector (USB connector).

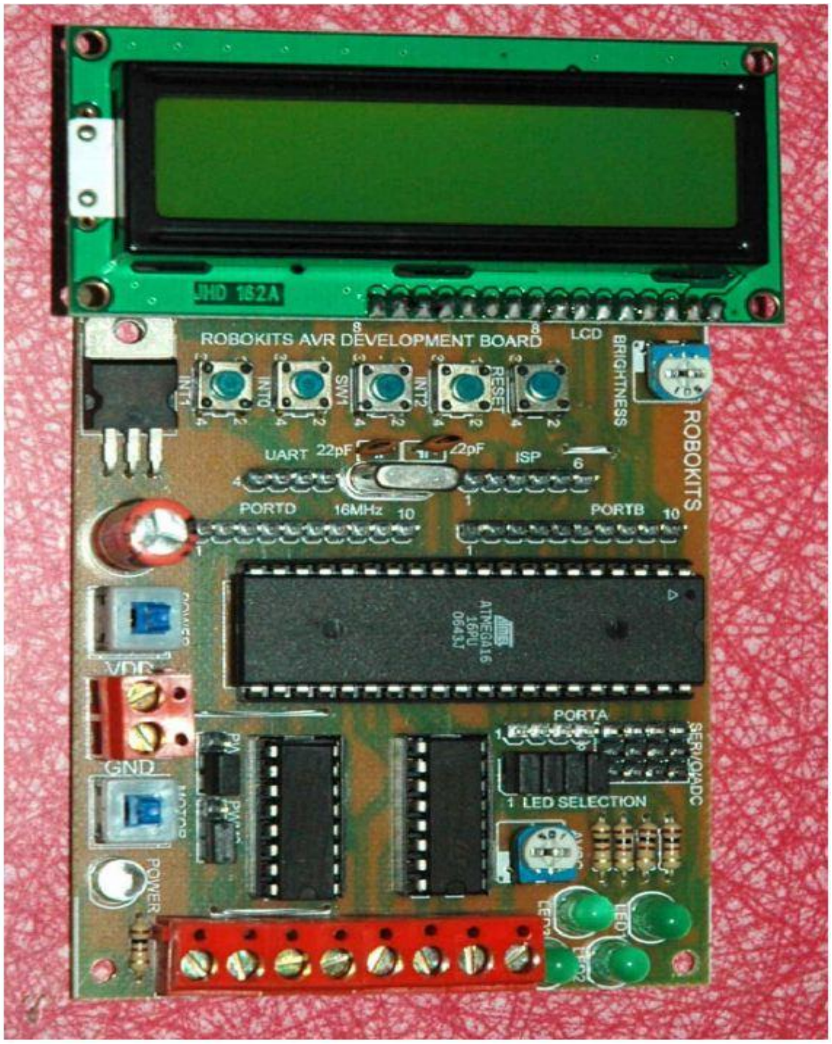
5.) USB Programmer (to burn the hardware program into Atmega board).

6.) One-to-one connector (to connect IR-sensors to the Board).

Here the ATMEGA 640 Board is interfaced with the PC. The type of communication done between the PC and the Board is serial i.e. bit-by-bit the information is transferred between PC and Board and vice-versa. For implementing serial communication, serial port and a USB serial-port connector is used. The IR-sensors are connected to the Board using one-to-one connector. A Motor is also connected to the Board which in turn is connected to the control barrier. The required program is written in WINAVR and the IDE used is AVR-Studio. The program is then burnt into the Board using a USB-Programmer.

4.3 Hardware Specification

1. AVR 40 pin rapid Development Board



The above picture is of AVR 40 pin rapid Development Board in which ATmega 32 Microprocessor is used. This controller board is used to communicate with the PC. Some of the important features of this board are:

- Can be easily power from an AC ± DC source or Battery

- On Board Regulator with filters and operating voltage from 6V - 20 V
- 5 Switches including reset
- Power on/off toggle switch
- Motor on/off toggle switch
- 16MHz crystal for maximum speed
- Onboard LCD connector compatible to HD44780 LCD Modules
- LCD brightness control
- PWM pins connected to motor drivers for speed control of motors
- Serial Programmer and PC-MCU serial link included
- Programmer, Serial port and Power Supply are provided externally which helps keeping the board size small.

Basically this board is connected with the PC using serial communicator (USB connection). So the data is transferred between them bit by bit. An adapter is used to supply power to the controller board and a USB programmer is used to burn the hardware program (written in WINAVR) into the AVR board.

2. <u>Sharp GP2D120 Distance Measurement sensor</u>

Some of the features of this sensor are:

- Very Small in size
- Less influence on the color of reflected objects, reflectivity
- Analog voltage corresponding to distance
- Detecting distance of 4 to 30 cm
- External control circuit unnecessary

This sensor is basically used to check for the presence of any vehicle. Two sensors of this type are used. The reason behind this is that the presence of any vehicle is confirmed only when both the sensors are getting blocked. So a human or any other object (which are not as wide as car OR not standing at the cross-section of these sensors) will be discarded.

4.4 Working of the Hardware

1) The ALPR program in the PC will be run and that program will be polling for "ALERT" signal from the hardware circuit.
2) At first, the IR-Sensors will be continuously polling for the presence of the vehicle. As soon as a vehicle comes, the paths of the IR-Sensors will be blocked.
3) As the vehicle moves forward and as the distance between the vehicle and the barrier becomes less than a certain threshold then a "ALERT" signal will be send by the Board to the PC.
4) Now, the hardware program will be waiting for a 'Y' OR 'N' signal from the PC.
5) As the ALPR program in the PC is polling for the "ALERT" signal, then upon getting this signal, the image of the car will be captured.
6) The whole ALPR Algorithm will be executed, starting from the LP detection, LP Segmentation, LP recognition then comparing the recognized License plate number with the database of valid license-plate numbers.
7) If the recognized number is matched with any of the database number, then the vehicle will be considered "AUTHENTICATED" else the vehicle will be considered as "UNAUTHENTICATED".
8) Depending upon the authenticity OR inauthenticity, the PC will send a 'Y' OR 'N' signal respectively to the hardware circuit.
9) As the hardware program is waiting for the signal, upon receiving the corresponding signal, further tasks will be performed.
10) If the signal is 'N', then the hardware circuit will show "UNAUTHENTICATED VEHICLE" in the LCD Screen and the barrier will not move.
11) If the signal is 'Y', then the hardware program will show "AUTHENTICATED VEHICLE" in the LCD Screen and the barrier will be open to let the valid-vehicle come inside.

4.5 Results and Discussion

After running the program on various test images properly recognized characters in 79% cases. The license plate detection approach presented in Section III was used to obtain license plate images. Totally 250 different test images were included in the experiment. All candidate images are processed in one format, i.e. white characters on a black background. The binary enhanced license plate images obtained from our proposed method was sent to the recognition program for recognition. In this paper, the sample space for experiments included a variety of test images containing Indian license plates, foreign license plates along with some of my own snapshots. After running the program on various test images, the accuracy for

LP detection → 65 %

LP Segmentation → 84 %

LP Recognition → 89 %

So, the total accuracy is 79 %.

The success rate table is shown below for Indian LP images, foreign LP images and images from my own camera.

Type of LP Image	Success Rate in LP extraction	Success Rate in Character Segmentation	Success rate of Character Recognition
Indian LP images	60	80	84
International LP images	75	85	92
LP images by our own camera	68	74	85

Chapter-5

Concluding Remarks

5. Concluding Remarks

In this report I have proposed a heuristic method to segment a license plate from an image. The algorithm used in this paper not only accelerates the process but also increases the probability of detecting the license plate and extraction of characters, under certain set of constraints. The process is successful through the steps of character width estimation, vertical height estimation, and segmentation of license plate into blocks and identification of these character blocks. Various well known techniques were used to come out with a final algorithm. The results show high accuracy of non-character area removal and thus better recognition of characters after their segmentation. The percentage accuracy for the entire process is found to be 80%.

The given ALPR system can be further improved by using the parallelization approach for various stages of development.

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