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An Automatic Number Plate Recognition System under Image Processing

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Abstract—Automatic Number Plate Recognition system is an application of computer vision and image processing technology that takes photograph of vehicles as input image and by extracting their number plate from whole vehicle image , it display the number plate information into text. Mainly the ANPR system consists of 4 phases: - Acquisition of Vehicle Image and Pre-Processing, Extraction of Number Plate Area, Character Segmentation and Character Recognition. The overall accuracy and efficiency of whole ANPR system depends on number plate extraction phase as character segmentation and character recognition phases are also depend on the output of this phase. Further the accuracy of Number Plate Extraction phase depends on the quality of captured vehicle image. Higher be the quality of captured input vehicle image more will be the chances of proper extraction of vehicle number plate area. The existing methods of ANPR works well for dark and bright/light categories image but it does not work well for Low Contrast, Blurred and Noisy images and the detection of exact number plate area by using the existing ANPR approach is not successful even after applying existing filtering and enhancement technique for these types of images. Due to wrong extraction of number plate area, the character segmentation and character recognition are also not successful in this case by using the existing method. To overcome these drawbacks I proposed an efficient approach for ANPR in which the input vehicle image is pre-processed firstly by iterative bilateral filtering , adaptive histogram equalization and number plate is extracted from pre-processed vehicle image using morphological operations, image subtraction, image binarization/thresholding, sobel vertical edge detection and by boundary box analysis. Sometimes the extracted plate area also contains noise, bolts, frames etc. So the extracted plate area is enhanced by using morphological operations to improve the quality of extracted plate so that the segmentation phase gives more successful output. The character segmentation is done by connected component analysis and boundary box analysis and finally in the last character recognition phase, the characters are recognized by matching with the template database using correlation and output results are displayed. This approach works well for low contrast, blurred, noisy as well as for dark and light/bright category images. The comparison is done between the ANPR with Adaptive Histogram Equalization and Iterative Bilateral Filtering that is the proposed approach and the existing ANPR approach using metrics: MSE, PSNR and Success rate.

Index Terms—Number plate extraction, adaptive histogram equalization, iterative bilateral filter, morphological opening, morphological closing, image binarization/thresholding, image subtraction, boundary box analysis, correlation.

I. Introduction

One of the important methods that are used in Intelligent Transportation System (ITS) is Automatic number plate recognition (ANPR). In transportation, Vehicles play important role. Day by day the human population is increased and use of vehicles is also increased due to increased human needs. As a result of it the control of vehicles is becoming a big complex problem. ANPR system is one of the methods used for the effective control of these vehicles [6] [17] that allow the extraction of number plate information without the needs of human. This automated system is an application of computer vision and image processing technology that allows one to extract number plate information from image or sequence of images. Image processing deals with the extraction of useful and meaningful information from digital images by various image processing techniques. Digital Image Processing (DIP) is a form of signal processing in which the input is a digital image or a video sequence and the output may be either an image or a set of features that are useful for solving real-world application-based problems. By using the various image processing techniques, ANPR system automatically identifies the vehicles by tracking their license plate without direct human intervention [6] [7] [20] [21] [22]. In an Automatic Number Plate Recognition (ANPR) pipeline, the input is a color or gray scale image or sequence of images (video related ANPR) and the output is a string of characters that is license plate number [1][20]. ANPR system is a combination of integrated software and hardware that will read vehicle number plates automatically without the need of humans [1] [6]. ANPR is an image processing technological solution that captured photographs of vehicles and firstly by detecting and extracting the number plate from whole vehicle image, it segments the characters from the plate area and

then by using the any of the character recognition technique for example template matching scheme, it display the license number plate information into text consists of numerical or string [6] [20] [21]. There are number of applications of ANPR, such as traffic monitoring, automatic ticketing of vehicles at parking area, tracking vehicles during signal violation, automatic toll collection at toll plaza, access control in parking areas and buildings, border control, stolen car detection, journey time measurement, marketing research, and in many other application with huge saving of human effort and cost [2] [9] [12]. ANPR is also known as License Plate Recognition (LPR), Car Plate Recognition (CPR), Vehicle Number Plate Recognition (VNPR), Number Plate Tracking (NPT), Automatic License Plate Reader (ALPR), Vehicle Number Recognition (VNR), Automatic Vehicle Identification (AVI) etc [2] [13] [21] [22] [23]. The quality of the captured input vehicle images is a major factor in the success of the ANPR. ANPR as a real-life application has to quickly and successfully process number plate's information under any environmental conditions, such day or night time. It should also process license plates from different nations and states [2]. Almost in all developed and developing counties the attributes/properties of the license plates are strictly maintained. The attribute are:- size of license plate (aspect ratio), background color of license plate, color of background characters, font(character style), spacing between subsequent characters, font size, scripts, number of lines in the license plate etc. are strictly maintained [20][24]. In standardized number plates aspect ratio is very important factor and mostly in all developed and in the developing countries the aspect ratio of vehicles license plate is same for all vehicles means that all the number plates are of same size where aspect ratio of a region (plate area) is defined as ratio of length to width (breadth) of that particular region and it is calculated as [9]

$$\text{Aspect ratio} = \text{Length}/\text{Width} \quad (1)$$

In India, There are two types of number plates used for two categories of vehicles. For private vehicles, the license plate is of white background with black characters on it as shown in fig.1. For commercial vehicles (trucks, taxi, bus), the license plate is of yellow background with back color characters on it as shown in Fig.2 [16]. Currently vehicle registration scheme in India consists of two-letter state code followed by two-digit numeric district code followed by series code followed by four digits registration number that is unique for each vehicle. Fig. 3 indicates the sample of an Indian private vehicle number plate in which 1 represent state code, 2 represent district code, 3 represent series code, and 4 represent actual registration number that uniquely identifies each vehicle [8] [16].

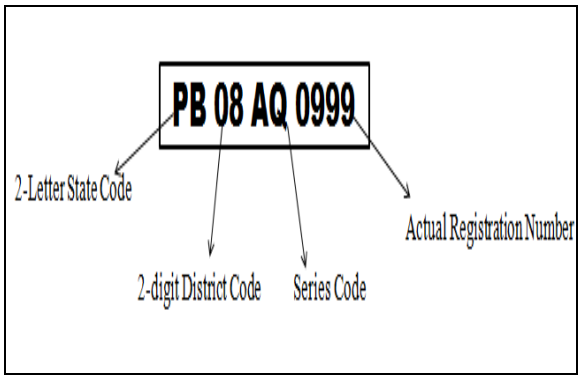

Fig.1. Indian License Plate for Private vehicles

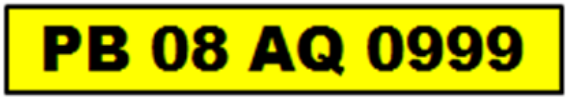

Fig.2. Standard Format for Indian License plate for Commercial vehicles

In India, no standard followed for the aspect ratio of license plates. This factor makes the extraction of Indian license plate more difficult as compared to the foreign license plates [9].

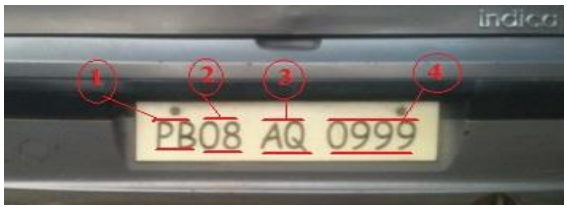

Fig.3. Sample of Indian vehicle License Plate

ANPR typically includes four steps: Acquisition of Image and Pre-Processing, Number Plate Detection (NPD) and Number Plate Extraction (NPE), Character Segmentation (CS) and Character Recognition (CR) as shown in Fig. 4 [21]:-

1) Acquisition of Image and Pre-processing
2) Number Plate Extraction (NPE)
3) Character Segmentation (CS)
4) Character Recognition (CR)

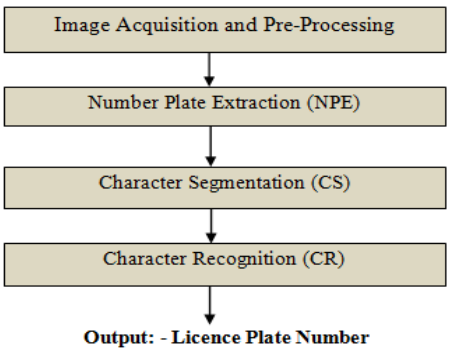

Fig.4. The Basic Working of ANPR System

Image Acquisition means how to acquire the input image. So in first phase the vehicle image is captured and some pre-processing steps are performed on it to increase its quality. Mainly in ANPR system digital camera of high resolution is used to capture the vehicle image and the captured image is of RGB format. After this, Pre-processing is performed on this input RGB image in which input RGB image is converted into gray scale image and then into binary using thresholding level. The noisy images are filtered by various filters to remove noise from them. The basic aim of pre-processing phase is to increase the processing speed by removing noise and by improving the contrast of the image. The output of this phase is the vehicle image of good quality [1] [21] [22] [23]. The Number Plate Extraction (NPE) is the second and most important phase of ANPR. The captured input image has number plate covered by vehicle body, so by this step only the number plate area is firstly detected and then extracted from whole vehicle image. The number plate extraction (NPE) phase influence the accuracy of ANPR system because all further steps depend on the accurate extraction of number plate area. The input to this stage is vehicle image and output is a portion of image containing the exact number plate [2]. Number plate detection aims at the spatial identification of the number plate within the input image. Techniques based on combinations of edge statistics, texture and mathematical morphology are the most popular for detection of the plate region [1]. There are various image processing and artificial intelligence techniques used for the detection of number plate location from the input vehicle image. Character Segmentation (CS) acts as bridge between the number plate extraction and character recognition phase. In this phase the characters on number plate area are segmented or separated one by one. There are many factors such as image noise, space mark, plate frame, plate rotation and illumination variance etc. that make the character segmentation task difficult. Incorrectly segmented characters result in unsuccessful recognition. Most of the recognition errors in the ANPR systems are not due to lack of recognition techniques but due to segmentation errors [1]. Character recognition (CR) is the last phase of ANPR system. The inputs to this phase are segmented characters and output of this phase is license plate number. In this phase the segmented characters are recognized. Character recognition (CR) in ANPR system has some difficulties. Sometimes the segmented or extracted characters do not have the same size. The better way to overcome this problem is to resize the characters into one size before the start of recognition.

The ANPR system is efficient only when it properly identifies and locates the vehicle number plate information and its main aim is to replace the manual systems with an automated system. The overall accuracy and efficiency of whole ANPR system depends on number plate extraction phase as character segmentation and character recognition phases are also depend on the output of this phase. Further the accuracy of Number Plate Extraction phase depends on the quality of captured vehicle image. Higher be the quality of captured input vehicle image more will be the chances of proper extraction of vehicle number plate area. The captured input vehicle images can be of image category:-Low Contrast, Blurred, Noisy, Dark and Light/Bright etc. The low contrast, blurred and noisy images have low quality than dark and light/bright category images. The existing methods of ANPR works well for dark and bright/light categories image but it does not work well for Low Contrast, Blurred and Noisy images and the detection of exact number plate area by using the existing ANPR approach is not successful even after applying existing filtering and contrast enhancement technique for these types of images. Due to wrong detection, the extraction of exact number plate area is not possible and as a result of it character segmentation and character recognition is not successful as these processes depend on accurate extraction of number plate area. So we should concentrate on improving the quality of input image in pre-processed phase. Sometimes the extracted plate area also contains noise, bolts, frames etc. These make character segmentation difficult. So enhancement of extracted plate region should be done for successful segmentation.

This paper is organized in V sections. Literature survey and the proposed approach for automatic number plate recognition are shown in section II and section III respectively. Experimental results and Conclusions and future work are given in section IV and section V respectively.

II. Literature Survey

Christos-Nikolaos E. Anagnostopoulos presented a brief tutorial on LPR. LPR includes three steps: - license plate detection, character segmentation (CR) and optical character recognition (OCR). This paper provides a brief review of literature, according to their methodology used in the three steps of license plate recognition [1]. Shan Du, Mahmoud Ibrahim, Mohamed Shehata and Wael presented survey on existing ALPR techniques by categorizing them according to the features used in each phase and compare them in terms of recognition accuracy, processing speed, pros and cons, [2]. Sahil Shaikh, Bornika Lahiri, Gopi Bhatt and Nirav Raja proposed method for number plate recognition. For plate localization, several images processing techniques: - enhancement, component analysis and edge detection are used. Connected component method used for extraction of individual number plate characters. Template Matching is used for Character Recognition [3]. Norizam Sulaiman proposed the development of automatic vehicle plate detection system. In this method after pre-processing the candidate plate is detected by some feature extraction method, character segmentation is done by boundary box analysis and character recognition is done by template matching [4].

Reza Azad and Hamid Reza Shayegh proposed a fast and real time method which has an appropriate application for tilt plates [5]. Ronak P Patel, Narendra M Patel and Keyur Brahmbhatt proposed new algorithm for recognition of number plate. Morphological operation,

Boundary box analysis and edge detection are used for number plate extraction and character recognition using Feature extraction [6]. Najeem Owamoyo, A. Alaba Fadele and Abimbola Abudu presented Automatic Number Plate recognition for the Nigerian vehicles in which number plate extraction is done using Sobel edge filter, morphological operations and connected component analysis, vertical projection analysis is used for character segmentation [7]. Sourav Roy, Amitava Choudhury and Joydeep Mukherjee presented a system for localization of number plate mainly for the vehicles in West Bengal. This approach is based on morphological operation and sobel edge detection method. An enhancement of contrast of the binarized image is done using histogram equalization [8]. Divya Gilly and Dr. Kumudha Raimond presented an efficient method for LPR system mainly consists of: - plate detection (PD), segmentation of characters (CS) and character recognition (CR) phase. This method consists of template matching technique [9]. Isack Bulugum presented an algorithm that is used to recognize the license plate from the front end and rear end of the vehicle. The methods that are used during implementation of the system are: Pre-processing, Plate Extraction, Character Segmentation (CR) and Character Recognition [10]. Rupali Kate presented proposed algorithm based on morphological operation with certain area criteria tests for number plate detection. Segmentation of the plate characters was achieved by the application of region props, labelling and fill hole approach [11]. P.Mohan Kumar, P.Kumaresan and Dr.S.A.K.Jilani presented Real time vehicle license plate identification system. This approach is based on region-props image processing technique [12]. Shoaib Rehman Soomro, Mohammad Arslan and Javed Fahad Ahmed proposed the system that consists of five steps. (1) Detection of the vehicle & capturing the image of front view of vehicle (2) Extract & localizing number plate area using vertical edging (3) Number plate segmentation & character separation (4)Template matching using correlation to convert characters of pixel value to alphanumeric/string value. (5) Using detected license number to charge toll tax accordingly [13].

Xiaojun Zhai, Faycal Bensaali and Reza Sotudeh proposed an Artificial Neural Network based OCR algorithm for ANPR application [14]. Hadi Sharifi Kolour presented the study and evaluation of some most important License Plate Detection algorithms and compared them in terms of complexity, accuracy, performance. Gabor transform is the most accurate and dynamic programming is fastest as compared to other algorithms [15]. L N P Boggavarapu, J K Munagala, R S Vaddi and K R Anne proposed the morphological based method that suits for the Indian context [16]. Kumar Parasuraman and P.Vasantha Kumar prsented an algorithm consist of 3 parts. Edge detection and vertical projection method are used for the extraction of plate region. In segmentation part, thinning, vertical and horizontal projection is used. And finally, chain code concept is used for recognition of the characters [17]. S. Hamidreza Kasaei, S. Mohammadreza Kasaei and S. Alireza Kasaei presented a real time and robust way of number plate localization and recognition based on the morphology operations and template matching method [18]. Chirag N. Paunwala, Dr. SupravaPatnaik and Manoj Chaudhary proposed multiple license plate detection algorithms based on component filtering and mathematical morphology. The algorithm is able to detect both single and multiple license plates accurately [19]. Satadal Saha, Subhadip Basu, Mita Nasipuri and Dipak Kumar Basu concentrated on localization of license plate regions from still snapshots. This technique is based on a multi-stage approach for the analysis of edge gradients from contrast stretched gray-scale images [20].

This paper represent an efficient approach for ANPR in which the input vehicle image is firstly pre-processed using iterative bilateral filter and adaptive histogram equalization and number plate is extracted from pre-processed vehicle image using morphological operations, image subtraction, image binarization/thresholding, sobel vertical edge detection and by boundary box analysis. After the extraction of plate area, the extracted plate is enhanced by using morphological operations to improve the quality of extracted plate so that the segmentation phase gives more successful output. The character segmentation is done by connected component analysis and boundary box analysis and finally in the last character recognition phase the characters are recognized by matching with the template database using correlation and output result are displayed. This approach works well for low contrast, blurred, noisy as well as for dark and light/bright category images. The comparison is done between the ANPR with Adaptive Histogram Equalization and Iterative Bilateral Filtering that is the proposed approach and the existing ANPR approach using metrics:- MSE, PSNR and Success rate.

III. Proposed Approach for ANPR

The proposed approach for automatic number plate recognition system is represented in this section. The existing ANPR methods works well for dark and light/bright images but it does not work well for low contrast, blurred and noisy images. But this proposed approach for ANPR works well for low contrast, blurred and noisy images as well as for dark and light/bright images. The proposed approach is divided into 4 main parts as shown in Fig. 5 and the steps under these phases are:

1) Acquisition of Input Image
2) RGB to Grayscale conversion
3) Noise removal by using Iterative Bilateral Filter
4) Contrast enhancement by Adaptive Histogram Equalization (AHE)
5) Morphological Opening and Image Subtraction
6) Image Binarization /Thresholding
7) Vertical Edge detection by Sobel operator
8) Candidate Plate Area Detection
9) Actual Extraction of Number Plate Area
10) Enhancement of Extracted Plate Area

11) Character Segmentation (CS)
12) Character Recognition (CR)

The steps 1-4 (image acquisition, RGB to grayscale conversion, Noise removal using iterative bilateral filter, and contrast enhancement using AHE) come under the Image Acquisition and Pre-Processing phase. The steps (5-10) come under the number plate extraction phase (NPE). The character segmentation consists of connected component analysis and boundary box analysis and finally template loading, character normalization and template matching using correlation is performed in character recognition phase.

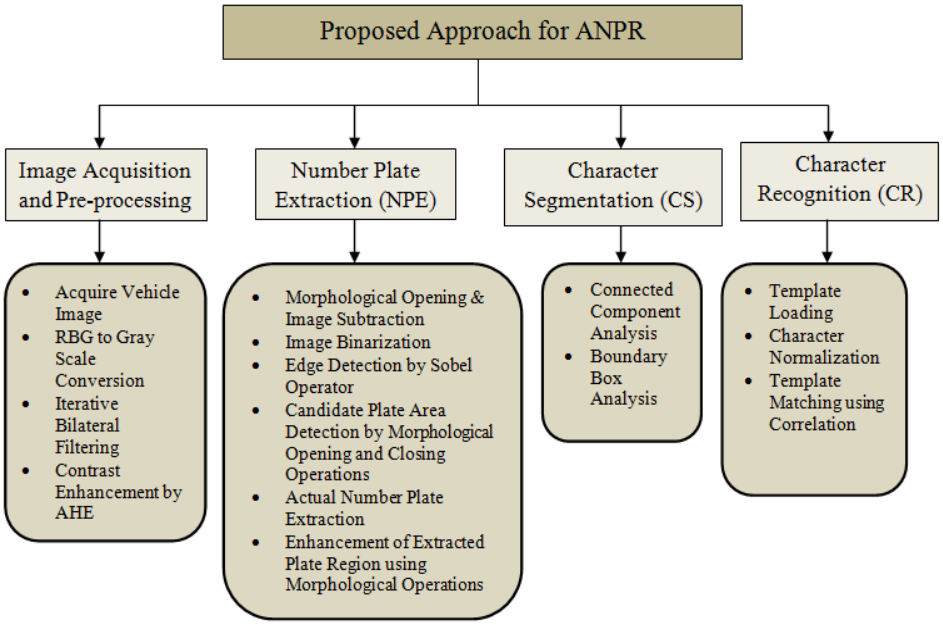

Fig.5. Sections of Proposed Approach for ANPR

1. *Image Acquisition*

The first step of ANPR is to capture the input vehicle image by means of digital camera. Different category of images can be acquired during camera capturing. Our database consists of five categories of images that are Light Images, Dark Images, Low Contrast Images, Blurred Images and Noisy Images. The light image is one which has histogram very far from origin. The dark image is one which has histogram very near to origin. A low contrast image occur due to poor illumination and it has narrow and at middle histogram. Blurred image is one which is not clear. Weather conditions such as snow, fog, rain are responsible for introducing "noise" during camera capturing. Fig. 6 shows the low contrast vehicle image and its histogram is shown in Fig.7 which is narrow and in middle.

Fig.6. Low Contrast Input Vehicle Image

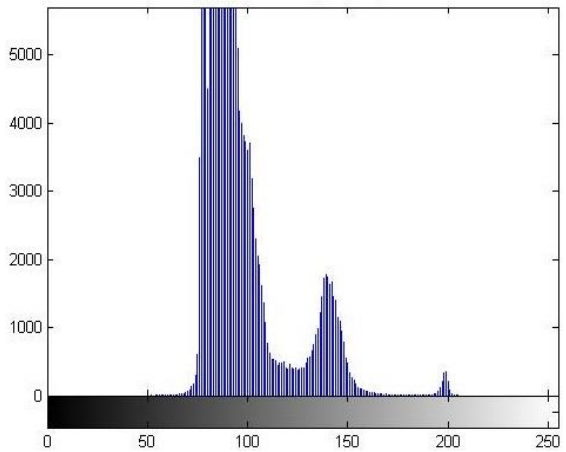

Fig.7. Histogram of Input Image

2. *Pre-Processing*

The basic aim of pre-processing is to improve the contrast of the input image, to reduce the noise in the image and hence to enhance the processing speed and to increase the visibility and quality of input image. In the proposed approach for ANPR, in pre-processing step firstly the RGB image is converted into gray scale image, then iterative bilateral filter is used to remove the noise from the gray scale image and finally the filtered image is enhanced by Adaptive Histogram Equalization (AHE) technique as follow:

i) Conversion of RGB to Gray Level image: The captured input vehicle image is in RGB format. In this step RGB image is converted into gray-scale image as shown in Fig. 8.

Fig.8. Gray Scale Image

ii) Noise Reduction by Iterative Bilateral Filter: Iterative bilateral filter is used in proposed approach that provides the mechanism for noise reduction while preserving edges more effectively than the median filter. The iterative bilateral filter results into less blurring effect while smoothing an image than the median filter. The image reconstructed with iterative filter has high PSNR and low MSE value as compared to the image reconstructed with the median filter. Hence the image filtered with iterative bilateral filter has better quality than the image reconstructed with median filter. Fig.9. shows the image filtered by iterative bilateral filter.

Fig.9. Result of applying iterative bilateral filter

iii) Contrast Enhancement using Adaptive Histogram Equalization: Contrast is the difference between lowest and highest intensity level. In the proposed approach the contrast is enhanced by adaptive histogram equalization (AHE). In AHE the test functions according to which we enhance the contrast of input image depend upon gray levels of image, local properties and spatial co-ordinates of pixels while in case of histogram equalization (HE), the test function value depend only on the gray levels of image. The image reconstructed with adaptive histogram equalization (AHE) has high PSNR and low MSE value as compared to the image reconstructed with histogram equalization (HE). Hence the image enhanced by AHE has better quality than the image that is enhanced with histogram equalization. Fig.10 shows contrast enhancement by AHE.

Fig.10. Contrast Enhancement using Adaptive Histogram Equalization

3. Morphological Opening and Image Subtraction Operations

Firstly the disc shaped structuring element (SE) is created and then the opening operation is performed on the adaptive contrast enhanced image by this structuring element (SE). After this, in the image subtraction operation, the morphological opened image is subtracted from adaptive contrast enhanced gray scale image so that the number plate region gets highlighted. Fig. 11 shows the result of opening operation and fig. 12 shows the result of image subtraction between the contrasts enhanced gray scale image and opened image.

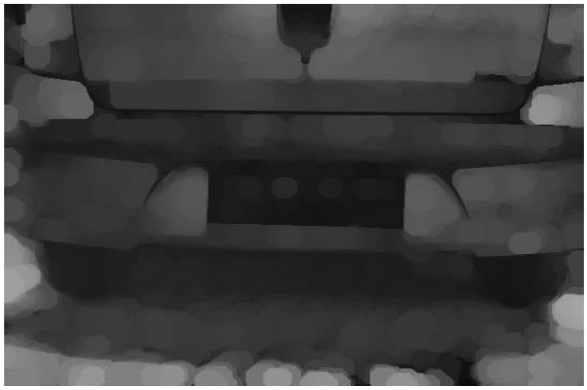

Fig.11. Opening effect using disk

Fig.12. Image Subtraction

4. Image Binarization

The image is converted to black and white format in this step. The purpose of applying color conversion is to reduce the number of range of the color scale from (0-255) to (0-1). In this step the subtracted gray scale image is converted into binary image. Firstly the global threshold level is calculated by using Otsu's method [9] and after this according to the calculated threshold value; the subtracted gray scale image is converted into black and white image. Fig. 13 shows binarized image.

Fig.13. Binarized Image

5. Edge Detection by Sobel Operator

Edges are detected by sobel operator. Sobel operator consists of two types of masks. One is horizontal sobel mask and vertical sobel mask. The result of applying sobel operator to binarized image is shown in Fig.14 as follow:-

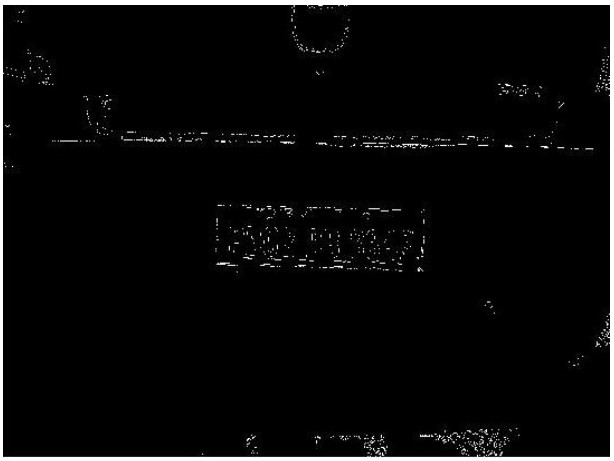

Fig.14. Edge Detection by Sobel operator

6. Detection of Number Plate Region by Opening and Closing Operations

For the detection of candidate plate area, firstly dilation operation is applied on this edge detected image and then the holes are filled in this dilated image using MATLAB *imfill* function. After this the unwanted portion of image is removed by using opening operation and finally the candidate plate region is detected by using morphological erosion operation. The result of applying dilation and filling holes is shown in fig. 15 and 16 respectively. Then morphological opening and morphological erode operations are used for detection of exact candidate plate area (NPD) and its result in shown in Fig. 17.

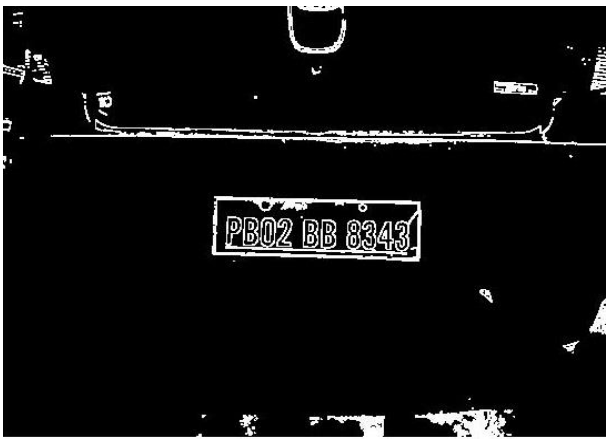

Fig.15. Morphological Dilation Operation

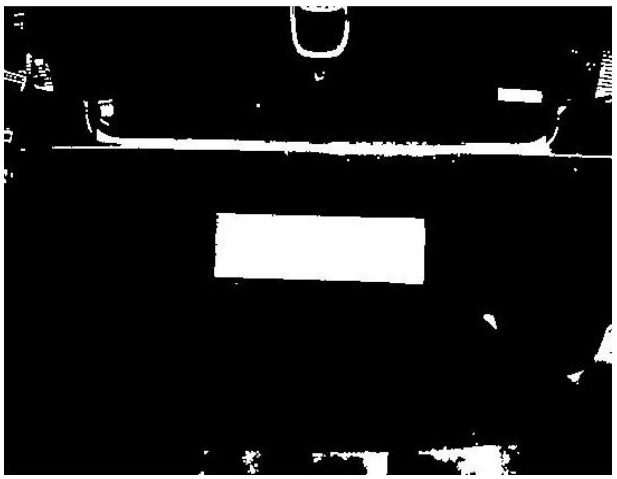

Fig.16. Image after filling holes

Fig.17. Number Plate Area Detection

7. Actual Number Plate Area Extraction

After the detection of number plate area that area is extracted from the image. The efficiency of number plate extraction depends on accurate detection of number plate area. In the proposed approach, after the detection of candidate plate area, the row and column indices of plate area plate area are found by Boundary Box Analysis (BBA) and then that portion is extracted from the image. Fig. 18 shows the actual extracted number plate area.

Fig.18. Extracted Number Plate Region

8. Extracted Plate Region Enhancement

The extracted number plate may consist of various noise, unwanted holes, frames, bolts etc. So enhancement of plate region is done. In the proposed approach the enhancement of extracted plate region is done by using various morphological operations. Fig.19 shows the result of plate region enhancement by morphological dilation, erosion, opening and closing operation on extracted plate region.

Fig.19. Enhanced Plate Region

9. Character Segmentation

Character Segmentation (CS) step acts as bridge between the number plate extraction and character recognition phase. In this phase the characters on number plate area are separated or segmented. There are many factors such as image noise, space mark, plate frame, plate rotation and illumination variance etc. that make the character segmentation difficult. In the proposed approach the character segmentation is done by Connected Component Analysis (CCA) and Boundary Box Analysis (BBA). Firstly labels are assigned to connected components and the labeled characters are extracted using boundary box analysis. Fig.20 shows the result of character segmentation.

10. Character Recognition

Character recognition (CR) is the last phase of ANPR system. The inputs to this phase are segmented characters and output of this phase is license plate number. The character recognition is done by template matching (TM) using correlation. Correlation is the degree of similarity between the segmented characters and the template characters. In the character recognition step firstly make template by taking 42 X 24 pixel A to Z alphabet and 0 to 9 number images. Read all image and store them in database and this result into 36 character templates. After the loading of templates, character normalization is done. In character normalization, all the segmented characters are resized to template size 42 X 24. Sometimes the segmented characters do not have the same size so the better way to overcome this problem is to resize the characters into one size (equal to template size) before actual recognition starts. In last the segmented characters are matched with template characters using correlation. The similarity between the template characters and segmented characters is measured and the template that is most similar to the character is recognized as target. The value of correlation is calculated by comparing the normalized segmented character image with each template character image and selecting the most relevant image and writes that character into text file. Fig.21 shows the result of character recognition.

Fig.20. Output of Character Segmentation

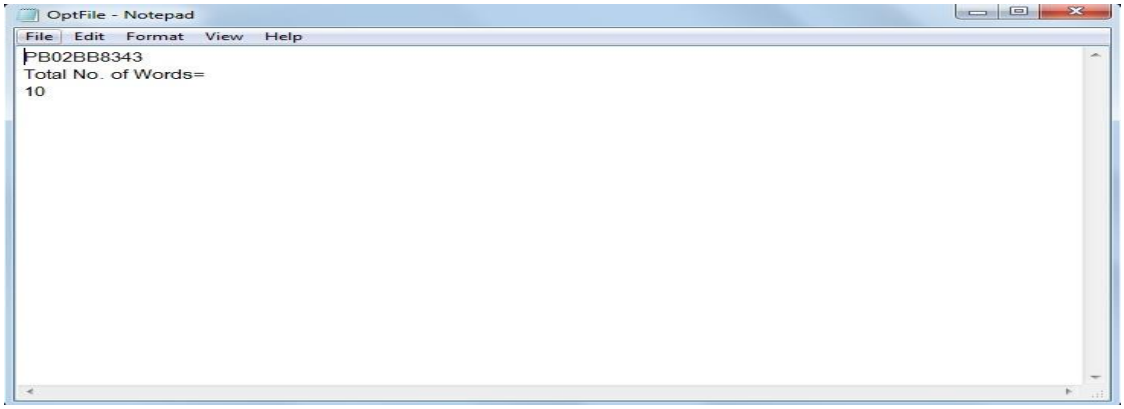

Fig.21. Output of Character Recognition

The existing ANPR method does not work well for Low Contrast, Blurred and Noisy images. But the proposed ANPR approach works well for Low Contrast, Blurred and Noisy images as well as for Dark and Light images. For example the input image as shown in fig.6 is of low contrast. When we applied the existing ANPR algorithm on this low contrast image, the extracted plate is not actual number plate area. As a result of this wrong extraction of license plate area, the character segmentation and character recognition are also not successful in this case because these two phases are depends on successful extraction of number plate area. But when we applied the proposed approach for ANPR on this low Contrast image, it properly extracts the actual plate area. After the extraction of plate area, the extracted plate is enhanced by using morphological operations to enhance the quality of extracted plate so that the segmentation gives successful output. The character segmentation and character recognition is also successful in this case.

IV. Experiment Results

This proposed approach for automatic number plate recognition system works well for low contrast, noisy and blurred as well as dark and light/bright input images. Total 120 vehicle's images are tested. Images are taken in different illumination conditions. The images are taken at different distances relative to camera and are of different colors and different sizes images. The database consists of low contrast, blurred, noisy, dark and bright/light category images. The proposed approach is tested on various real time images of these different image categories by using various performance metrics namely Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE) and Success Rate. In the proposed approach the value of MSE is low than the existing ANPR method. The success rate (%) in each phase of ANPR and PSNR is higher than that of existing ANPR method. The result of proposed approach for number plate extraction is shown in TABLE 1-7 and this is implemented in MATLAB 7.8.0.

1. PSNR (Peak Signal to Noise Ratio)

PSNR is used as a quality measurement metric to measure the quality between original and reconstructed image. Higher the PSNR value, better the quality of the reconstructed image. To Compute PSNR firstly MSE is calculated and then PSNR is calculated in decibels **(dB),** using following equation

$$PNSR = 10\log 10\left[\frac{R^2}{MSE}\right] \quad (2)$$

Where R is the maximum possible pixel and MSE is the Mean Square Error. The PSNR value is calculated by existing and proposed ANPR method as shown in table 1-3 for each category of image as follow:-

i. Comparison of PSNR for Different Category Images using Median Filter (Existing Method) and Iterative Bilateral Filter (Proposed Method).

Here the comparison of PSNR value is done for different category of images using median filler and Iterative bilateral filter. The PSNR value is high for each category of image using proposed method than the existing method as shown in table 1.

Table 1. PSNR for different Images using Median Filter and Iterative Bilateral Filter Technique

Filtering Method	PSNR				
	Low Contrast Image (Image1)	Noisy Image (Image2)	Blurred Image (Image3)	Dark Image (Image4)	Light Image (Image5)
Median Filtering (Existing Method)	36.676	30.437	36.773	33.333	30.322
Iterative Bilateral Filtering (Proposed Method)	37.608	33.006	37.244	34.179	32.181

ii. Comparison of PSNR for Different Category Images using Histogram Equalization (Existing Method) and Adaptive Histogram Equalization.

Here the comparison of PSNR value is done for different category of images using histogram equalization and adaptive histogram equalization. The PSNR value is

high for each category of image using proposed method than the existing method as shown in table 2.

Table 2. PSNR for different of Images using Histogram Equalization and Adaptive Histogram Equalization Technique

Enhancement Method	PSNR				
	Low Contrast Image (Image1)	Noisy Image (Image2)	Blurred Image (Image3)	Dark Image (Image4)	Light Image (Image5)
Histogram Equalization (HE) (Existing Method)	20.990	15.755	16.445	16.480	25.363
Adaptive Histogram Equalization (AHE) (Proposed Method)	26.355	24.936	22.764	23.745	25.976

iii. Comparison of PSNR for Number Plate Extraction Operations using Median Filter and Histogram Equalization (Existing Method), Iterative Bilateral Filter and Adaptive Histogram Equalization (Proposed Method) for Different Category Images.

Here the comparison of PSNR value for different number plate extraction steps (morphological opening, image binarization, sobel edge detection, candidate plate area detection) is done for different category of images using median filter and histogram equalization (existing method) and iterative bilateral filter and adaptive histogram equalization (Proposed method). The PSNR value is high for each category of image using proposed method than the existing method as shown in table 3.

Table 3. PSNR for Number Plate Extraction Operations using Median Filter and Histogram Equalization (HE), Iterative Bilateral Filter and Adaptive Histogram Equalization (AHE) Technique

Number Plate Extraction Step	Method	PSNR				
		Low Contrast Image (Image1)	Noisy Image (Image2)	Blurred Image (Image3)	Dark Image (Image4)	Light Image (Image5)
Morphological Opening	Existing Method	21.553	18.816	19.901	18.906	15.693
	Proposed Method	22.772	29.907	21.820	22.656	16.050
Image Binarization	Existing Method	13.263	16.638	15.128	17.857	13.595
	Proposed Method	13.739	18.730	15.858	18.528	14.517
Sobel Edge Detection	Existing Method	13.194	17.538	16.130	17.550	12.172
	Proposed Method	13.554	18.210	16.283	17.667	12.399
Candidate Plate Area Detection	Existing Method	13.218	17.944	15.452	17.594	12.858
	Proposed Method	13.748	18.247	15.657	17.806	12.995

2. MSE (Mean Square Error)

MSE means the cumulative squared error between the original image and reconstructed image. Lower the value of MSE, lower is the error present in the image so better is the quality of reconstructed image. The mean square error (MSE) between original and reconstructed image is defined as

$$MSE = \frac{1}{MN}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1}\left(a(m,n) - b(m,n)\right)^2 \quad (3)$$

Where a (m, n) and b (m, n) represent the original image and reconstructed image respectively and M, N are no. of rows and columns in the input image respectively. The MSE value is calculated by existing and proposed ANPR method as shown in table 4-6 for each category of image as follow:-

i. Comparison of MSE for Different Category Images using Median Filter (Existing Method) and Iterative Bilateral Filter (Proposed Method).

Here the comparison of MSE value is done for different category of images using median filler and Iterative bilateral filter. The MSE value is low for each category of image using proposed method than the existing method as shown in table 4.

Table 4. MSE for different Images using Median Filter and Iterative Bilateral Filter Technique

Filtering Method	MSE				
	Low Contrast Image (Image1)	Noisy Image (Image2)	Blurred Image (Image3)	Dark Image (Image4)	Light Image (Image5)
Median Filtering (Existing Method)	13.979	58.794	13.671	30.180	60.375
Iterative Bilateral Filtering (Proposed Method)	11.279	32.545	12.267	24.843	39.356

ii. Comparison of MSE for Different Category Images using Histogram Equalization (Existing Method) and Adaptive Histogram Equalization (Proposed Method).

Here the comparison of MSE value is done for different category of images using histogram equalization and adaptive histogram equalization. The MSE value is low for each category of image using proposed method than the existing method as shown in table 5.

Table 5. MSE for different of Images using Histogram Equalization and Adaptive Histogram Equalization Technique

Enhancement Method	MSE				
	Low Contrast Image (Image1)	Noisy Image (Image2)	Blurred Image (Image3)	Dark Image (Image4)	Light Image (Image5)
Histogram Equalization (HE) (Existing Method)	517.718	1736.111	1474.161	1460.449	189.135
Adaptive Histogram Equalization (AHE) (Proposed Method)	150.501	208.701	344.080	274.497	143.034

iii. Comparison of MSE for Number Plate Extraction Operations using Median Filter and Histogram Equalization Technique (Existing Method), Iterative

Bilateral Filter and Adaptive Histogram Equalization Technique (Proposed Method) for Different Category Images.

Here the comparison of MSE value for different number plate extraction steps (morphological opening, image binarization, sobel edge detection, candidate plate area detection) is done for different category of images using median filter and histogram equalization (existing method) and iterative bilateral filter and adaptive histogram equalization (Proposed method). The MSE value is low for each category of image using proposed method than the existing method as shown in table 6.

Table 6. MSE for Number Plate Extraction Operations using Median filter and Histogram Equalization (HE) Technique, Iterative Bilateral Filter and Adaptive Histogram Equalization (AHE) Technique

Number Plate Extraction Step	Method	MSE				
		Low Contrast Image (Image1)	Noisy Image (Image2)	Blurred Image (Image3)	Dark Image (Image4)	Light Image (Image5)
Morphological Opening	Existing Method	454.801	854.018	665.233	836.608	1752.808
	Proposed Method	343.553	419.127	421.661	352.786	1614.625
Image Binarization	Existing Method	3067.419	1410.278	1991.845	1065.112	2841.504
	Proposed Method	2749.283	871.205	1687.725	912.538	2298.145
Sobel Edge Detection	Existing Method	3116.663	1146.377	1585.326	1141.716	3943.473
	Proposed Method	3074.934	981.819	1530.221	1112.605	3742.675
Candidate Plate Area Detection	Existing Method	3099.078	1043.906	1852.928	1131.676	3367.272
	Proposed Method	2743.210	974.364	1767.489	1128.505	3263.027

3. Success Rate (%)

Table 7. Success Rate (%) for Different Stages of ANPR using Existing and Proposed Method

Stages of ANPR	Algorithm	Total No. of Input Images	Success	Failure	Success Rate (%)
Number Plate Extraction	Existing	120	109	11	90.83%
	Proposed	120	117	3	97.50%
Character Segmentation	Existing	120	106	14	88.33%
	Proposed	120	117	3	97.50%
Character Recognition	Existing	120	104	16	86.67%
	Proposed	120	116	4	96.67%

The success rate is calculated for 3 different phases of ANPR. The success rate for number plate extraction phase is equal to the ratio of successfully extracted plates and total no. of input vehicle images. The success rate for character segmentation phase is equal to the ratio of successfully segmented plates and total no. of input vehicle images. The success rate for character recognition phase is equal to the ratio of successfully recognized plates and total no. of input vehicle images. If the ANPR approach gives higher value of success rate (%) it means that approach has better result as compared to ANPR approach that has low value of success rate. The success rate (%) is calculated for each phase of ANPR using existing and proposed approach as shown in table 7. The success rate (%) is higher in case of our proposed method as compares to existing method of ANPR.

V. Conclusion & Future Work

In Automatic Number Plate Recognition System the number plates are extracted from background vehicle images in number plate extraction phase. The Segmentation phase, segments the character individually and Character Recognition part recognize the segmented character. Number Plate Extraction is most crucial step in the ANPR system which influences the overall accuracy and processing speed of whole system as character segmentation and character recognition phases are also depend on extracted plate area that is the output of number plate extraction phase. Sometimes due to low quality, low contrast and noisy images we cannot detect and extract exact number plate location. As a result of this wrong extraction of number plate area, the character segmentation and character recognition are not successful in this case because these two phases are also depends on successful extraction of number plate area. The existing ANPR method works well for dark and bright/light categories image but it does not work well for Low Contrast, Blurred and Noisy images. But our proposed ANPR approach works well for Low Contrast, Blurred and Noisy images as well as for Dark and Light images. In our proposed approach, after the extraction of plate area, the extracted plate is enhanced by using morphological operations to enhance the quality of extracted plate so that the segmentation phase gives more successful output.

Our proposed approach for ANPR gives better result as compared to the existing ANPR method. We compare the result of proposed approach with the existing approach by using two performance metrics that are PSNR and Success Rate (%). Our proposed approach for ANPR gives better result than the existing ANPR method because the proposed approach gives higher value of PSNR and also high success rate (%) as compared to the existing ANPR method.

The future research of ANPR should concentrate on high definition plate image processing, multi-style plate recognition, and multi-plates processing at a time, video-based ANPR using temporal information and recognition of ambiguous characters and so on. So the main issues for future research are:

1. Multi-style plate recognition, high definition plate image processing and multi-plates processing.
2. For video-based ANPR we need to first extract the frames that have the passing cars. Extracting the correct frame with a clear vehicle number plate image is another challenge especially when the vehicle speed is very fast.

3. Future research should concentrate on improving the recognition rate for ambiguous characters such as (O-0), (I-1), (A-4), (C-G) and broken characters.

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