Automatic Number Plate Recognition System (ANPR): A Survey

Chirag Patel
Smt. Chandaben Mohanbhai Patel Institute of Computer Applications (CMPICA)
Charotar University of Science and Technology(CHARUSAT)

Dipti Shah, PhD.
G. H. Patel P.G. Department of Computer Science
S. P. University

Atul Patel, PhD.
Smt. Chandaben Mohanbhai Patel Institute of Computer Applications (CMPICA)
Charotar University of Science and Technology(CHARUSAT)

ABSTRACT

Traffic control and vehicle owner identification has become major problem in every country. Sometimes it becomes difficult to identify vehicle owner who violates traffic rules and drives too fast. Therefore, it is not possible to catch and punish those kinds of people because the traffic personal might not be able to retrieve vehicle number from the moving vehicle because of the speed of the vehicle. Therefore, there is a need to develop Automatic Number Plate Recognition (ANPR) system as a one of the solutions to this problem. There are numerous ANPR systems available today. These systems are based on different methodologies but still it is really challenging task as some of the factors like high speed of vehicle, non-uniform vehicle number plate, language of vehicle number and different lighting conditions can affect a lot in the overall recognition rate. Most of the systems work under these limitations. In this paper, different approaches of ANPR are discussed by considering image size, success rate and processing time as parameters. Towards the end of this paper, an extension to ANPR is suggested.

Keywords

Automatic Number Plate Recognition (ANPR), Artificial Neural Network (ANN), Character Segmentation Image Segmentation, Number Plate, Optical Character Recognition

1. INTRODUCTION

1.1 Automatic Number Plate Recognition (ANPR)

In last few years, ANPR or license plate recognition (LPR) has been one of the useful approaches for vehicle surveillance. It is can be applied at number of public places for fulfilling some of the purposes like traffic safety enforcement, automatic toll text collection [1], car park system [2] and Automatic vehicle parking system [3]. ANPR algorithms are generally divided in four steps: (1) Vehicle image capture (2) Number plate detection (3) Character segmentation and (4) Character recognition. As it is shown in Fig.1, the first step i.e. to capture image of vehicle looks very easy but it is quite exigent task as it is very difficult to capture image of moving vehicle in real time in such a manner that none of the component of vehicle especially the vehicle number plate should be missed. Presently number plate detection and recognition processing time is less than 50 ms [4] in many systems. The success of fourth step depends on how second and third step are able to locate vehicle number plate and separate each character. These systems follow different approaches to locate vehicle number plate from vehicle and then to extract vehicle number from that image. Most of the ANPR systems are based on common approaches like artificial neural network (ANN) [5], [1],[6],[7][8], [9], [10], Probabilistic neural network (PNN) [11], Optical Character Recognition (OCR)[5], [12], [2], [13], [7], [14], Feature salient [15], MATLAB[16], Configurable method[17], Sliding concentrating window (SCW)[14],[8], BP neural network[18], support vector machine(SVM)[19], inductive learning [20], region based [21], color segmentation [22], fuzzy based algorithm [23], scale invariant feature transform (SIFT) [24], trichromatic imaging, Least Square Method(LSM) [25],[26], online license plate matching based on weighted edit distance [27] and color-discrete characteristics [28]. A case study of license plate reader (LPR) is well explained in [29]. Some authors focus on improving resolution of the low-resolution

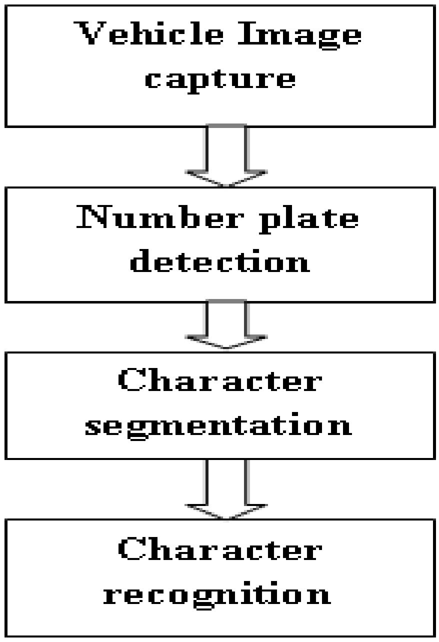

Fig.1. Conventional ANPR system

image by using technique called super resolution [30], [31]. Sometimes it becomes necessary to assess the quality of ANPR system. In [9], a quality assessment of visual and ANPR is well explained. A comprehensive study of License plate recognition (LPR) is well presented in [4]. Throughout this literature, number plate and license plate are used interchangeably. Details about each ANPR are discussed in section 2.

1.2 Scope of this paper

As it is not possible to judge which approach is better, different papers, which are based on steps mentioned in Fig.1, are surveyed and categorized based on the methodologies in each approach. For each approach whenever available parameters like speed, accuracy, performance, image size and platform are reported. Commercial product survey is beyond the scope of this paper as sometimes these products claims more accuracy than actual for promotional purposes. Remainder of this paper is divided as follows: Section 2 contains survey of different techniques to detect number plate. Character segmentation methods are reviewed in section 3 and section 4 contains discussion about character recognition methods. The paper concludes with the discussion of what is not implemented and what kind of research is possible in ANPR.

2. NUMBER PLATE DETECTION

Most of the number plate detection algorithms fall in more than one category based on different techniques. To detect vehicle number plate following factors should be considered:

(1). Plate size: a plate can be of different size in a vehicle image.

(2). Plate location: a plate can be located anywhere in the vehicle.

(3). Plate background: A plate can have different background colors based on vehicle type. For example a government vehicle number plate might have different background than other public vehicles.

(4). Screw: A plate may have screw and that could be considered as a character.

A number plate can be extracted by using image segmentation method. There are numerous image segmentation methods available in various literatures. In most of the methods image binarization is used. Some authors use Otsu's method for image binarization to convert color image to gray scale image. Some plate segmentation algorithms are based on color segmentation. A study of license plate location based on color segmentation is discussed in [22]. In the following sections common number plate extraction methods are explained, which is followed by detailed discussion of image segmentation techniques adopted in various literature of ANPR or LPR.

2.1 Image binarization

Image binarization is a process to convert an image to black and white. In this method, certain threshold is chosen to classify certain pixels as black and certain pixels as white. But the main problem is how to choose correct threshold value for particular image. Sometimes it becomes very difficult or impossible to select optimal threshold value. Adaptive Thresholding can be used to overcome this problem. A threshold can be selected by user manually or it can be selected by an algorithm automatically which is known as automatic thresholding.

2.2 Edge detection

Edge detection is fundamental method for feature detection or feature extraction. In general case the result of applying edge detection of algorithm is an object boundary with connected curves. It becomes very difficult to apply this method to complex images as it might result with object boundary with not connected curves. Different edge detection algorithm / operators such as Canny, Canny-Deriche, Differential, Sobel, Prewitt and Roberts Cross are used for edge detection.

2.3 Hough Transform

It is a feature extraction technique initially used for line detection. Later on it has been extended to find position of arbitrary shape like circle or oval. The original algorithm was generalized by D.H. Ballard [32].

2.4 Blob detection

Blob detection is used to detect points or regions that differ in brightness or color as compared to surroundings. The main purpose of using this approach is to find complimentary regions which are not detected by edge detection or corner detection algorithms. Some common blob detectors are Laplacian of Gaussian (LoG), Difference of Gaussians (DoG), Determinant of Hessian (DoH), maximally stable extremal regions and Principle curvature based region detector.

2.5 Connected Component Analysis (CCA)

CCA or blob extraction is an approach to uniquely label subsets of connected components based on a given heuristic. It scans binary image and labels pixel as per connectivity conditions of current pixel such as North-East, North, North-West and West of the current pixel (8-connectivity). 4-connectivity is used for only north and west neighbour of current pixel. The algorithm gives better performance and it is very useful for automated image analysis. This method can be used in plate segmentation as well as character segmentation.

2.6 Mathematical morphology

Mathematical morphology is based on set theory, lattice theory, topology, and random functions. It is commonly applicable to digital image but can be used in other spatial structures also. Initially it was developed for processing binary images and then extended for processing gray scale functions and images. It contains basic operators such as Erosion, dilation, opening, closing.

2.7 Related work in number plate detection

The methods discussed in preceding sections are common methods for plate detection. Apart from these methods, various literature discussed method for plate detection. As most of the methods discussed in these literatures use more than one approach, it is not possible to do category wise discussion. Different number plate segmentation algorithms are discussed below.

In [5], for faster detection of region of interest (ROI) a technique called sliding concentric window (SCW) is developed. It is a two step method contains two concentric windows moving from upper left corner of the image. Then statistical measurements in both windows were calculated based on the segmentation rule which says that if the ratio of the mean or median in the two windows exceeds a threshold, which is set by the, then the central pixel of the windows is considered to belong to an ROI. The two windows stop sliding after the whole image is scanned. The threshold value can be decided based on trial and error basis. The connected component analysis is also used to have overall success rate of 96%. The experiment was carried out on Pentium IV at 3.0

GHz with 512-MB RAM and took 111ms of processing time for number plate segmentation.

Another SCW based system is presented in [8] for locating Korean number plate. After applying SCW on vehicle image authors used HSI color model for color verification and then tilt was corrected by using least square fitting with perpendicular offsets (LSFPO). The distance between camera and vehicle varies from 3 to 7 meters.

A cascade framework was used in [33] for developing fast algorithm for real time vehicle number plate detection. In this framework a compact frame detection module is used to segment number plate. This module contains three steps: First - Generation of Plate Region Candidates which is used to reject non plate regions by using gradient features. Second – Extraction of complex plate regions which contains three steps to identify plate region and reject non plate regions. Third – plate verification is used to make sure that no non plate regions are extracted in preceding steps. The experiment was carried out on 3-GHz Intel Pentium 4 personal computer.

To detect multi-style number plate a configurable method is proposed in [17]. For detecting different style of number plates, a user can configure the algorithm by changing parameter value in the number plate detection algorithm. The authors define four parameters mainly:

- Plate rotation angle- to rotate number at certain angle plate if it is skewed which is shown in fig. 2(a).
- Character line number – to determine whether characters are spanned in more than one line or column as shown in fig. 2(b). The algorithm works for maximum three lines.
- Recognition models – to determine whether number plate contains alphabets only, alphabets and digits or alphabet, digits and symbols.
- Character formats – To classify the number plate characters based on their type. For example, Symbols can be represented as S, Alphabets can be represented as A and digits can be represented as D. So the number in fig.2, can be represented as AADAADDDD.

(a) Skewed image (b) Number plate with lines

Fig. 2. Vehicle number plate with first two parameters as per [17]

The algorithm was executed on Pentium IV 3.0GHz.

To locate Indian number plate, a feature based number plate localization is proposed in [34]. The authors use Otsu's method to convert gray scale images into binary images. It is a seven-step procedure to extract number plate without any background image from vehicle image.

In [15] a feature salient method is used to extract vehicle number plate by using salient features like shape, texture and color. The authors used Hough transform (HT) to detect vertical and horizontal lines from rectangular vehicle number plate and then processed it by converting red, green, blue (RGB) to hue-intensity-saturation(HIS). Finally, the number plate is segmented. This algorithm is executed on Pentium-IV 2.26-GHz PC with 1 GB RAM using MATLAB.

An Improved bernsen algorithm is used in [19] for license plate location. This algorithm is used for the conditions like uneven illumination and particularly for shadow removal. The authors used local Otsu, global Otsu, and differential local threshold binary methods for good accuracy. By using this algorithm, shadow was removed and license plate was successfully detected, which was not possible with the traditional bernsen algorithm. The experiment was carried out on Windows XP Operating system Intel Core 1.8 GHz central processing unit and 1.5 GB RAM. The algorithm was developed using Visual C++.

To locate Chinese number plate Hui Wu and Bing Li [35] proposed a method to find horizontal and vertical difference to find exact rectangle with vehicle number. The Authors converted vehicle image into gray scale and then applied automatic binarization using MATLAB. Any further detail regarding number plate detection algorithm is not mentioned in this paper. The authors claim to have average recognition rate of 0.8s.

To extract license plate characters in Indian condition Ch.Jaya Lakshmi et al. [16] proposed a novel approach which is based on texture characteristics and wavelets [36]. The authors also used morphological operation [37] for better performance in complicated background. Sobel mask is used to detect vertical edges. The system was implemented using MATLAB. A Sobel edge detector operator is also used in [38].

To detect license plate from CCTV footage, M.S.Sarfraz et al.[39] proposed a novel approach for efficient localization of license plates in video sequence and the use of a revised version of an existing technique for tracking and recognition. The authors proposed a novel solution for adjusting varying camera distance and diverse lighting conditions. License plate detection is a four step procedure including finding contours and connected components, selection of rectangle region based on size and aspect ratio, initial learning for adaptive camera distance/height, localization based on histogram, gradient processing, and nearest mean classifier. After processing these steps final detection result is forwarded for tracking.

In [6], canny edge detector operator was applied to find out the transition points. As per H.Erdinc Kocer et al a license plate contains white background and black character normally. The Canny edge detector uses a filter, which is then based on Gaussian smoothing's first derivative to eliminate the noise. Then in the next step, the edge strength is calculated by considering the gradient of the image. The canny edge detector operator used 3 X 3 matrix to accomplish this task. Based on this information transition points region is determined. The edge map is used to find transition points between black and white colors. The further technical details of this algorithm are not mentioned. The vehicle images were captures from CCD camera.

For detecting number plates of different countries Ankush Roy et al. [7] presented improved segmentation algorithm. The number plate segmentation algorithm is a four step procedure including median filtering, adaptive thresholding, component labeling and region growing and segmentation and normalization to remove noise, for binarization of image, to label the pixel according to color value and to segment the plate of 15 X 15 pixel size. The authors used Otsu's method for image binarization in the adaptive thresholding process. The overall success rate of system is mentioned but success rate of number plate detection rate is not mentioned in this paper.

In [14], global edge features and local Haar-like features are proposed for real-time traffic video. License plate detection is accomplished by moving a scanning window around the vehicle image. The scanning windows is categorized a license plate region and non license plate region based on the pre-defined classifier. In the training phase, six cascade classifier layers are constructed for future processing. In the testing phase, local Haar-like features and global features are extracted. Haar-like features are the digital image features generally used for object segmentation. These features are generally collection of functions to find number of rectangles covering adjacent image regions. Global features include edge density and edge density variable. These features are calculated by using fix size of sample image i.e. 48 X 16 which is scaled in training phase. The experiment was carried out on a PC with Pentium 2.8 GHz CPU. The average processing time for segmentation was 0.204s. Another edge based number plate segmentation algorithm is presented in [38].

A weighted statistical method is applied in [18]. Before processing further, authors converted 24 bit color image into gray scale image. In the weighted statistical method, a 2D image matrix of N rows and M columns is prepared. Then weighting operation is applied to the modified image matrix prepared after adding weights. As per Zhigang Zhanga et al. standard license plate length and breadth proportion is 3.14:1. More implementation details regarding this method are not mentioned in this paper. Similar method is proposed in [40].

To detect license plate in varying illumination conditions a novel approach is presented in [41]. A binarization method is used as pre-processing step for plate segmentation. In this approach, the author divided small window region in the image and applied dynamic thresholding method to each region. As per Naito, T et al. [41], this method is very robust for a local change in brightness of an image. Then binarized image is labelled and segmented as per the algorithm mentioned in this paper. The algorithm works for Japanese number plate but it is not clear that whether it can be applied for other countries. The experiment environment and processing time are not mentioned.

In [42] a novel approach based on vector quantization (VQ) is discussed. As per Zunino, R, most approaches focus on candidate regions like edge, contract etc in segmentation process. It might segment non plate regions rather than plate regions. So VQ based approach is able to solve this problem. As per this paper a license plate is assumed be a rectangular box and each rectangle regions are considered as stripes. By using four-step codebook algorithm, a license plate is segmented. The system was developed under C++ language with Intel Pentium board running at 200 MHz having Windows NT operating system. The overall processing time including acquisition, location and OCR is about 200ms.

In [43], license plate character extraction for video is discussed. As per Cui, Yuntao, localization of license plate means finding text in the images. The authors assumed license plate with light background and characters with dark back ground. To do localization, spatial variance method is used for finding text regions and non text regions as high variance means text region and low variance means non text region.

In [44] DT-CNN and classifier combining based VIPUR system (Vehicle Identification on PUblic Roads) is described. The system does automatic recognition of license plate for toll collection. The input is 8 bit gray scale image. As per Ter Brugge, M.H. et al. a license plate is rectangle area containing number of dark characters. To determine license plate region, greyness and texture features are applied to each pixel. To extract greyness feature DT-CNN is used which mentions that a 1 value indicates gray value and -1 indicates color of pixel is outside of the gray value. By using gray value a frequency table is prepared. Based on this table a value range is defined. The authors mentioned that gray value of most of the license plate characters ranges from 0.1 to 0.57. For texture feature a 3 X 3 Sobel operator is applied to each pixel to construct histogram. Most of the license plate pixels have absolute Sobel value more than 0.73. Then by using a two layer DT-CNN a 3 X 3 matrix is prepared, which is remitted to the next step for further processing. Next step is dimension based objection selection for locating license plate regions. In this method non plate regions are removed by considering weak size constraints minimum height, maximum height, minimum width and maximum width. This is done by four DT-CNNs. Finally one union and two subtraction operators are used for getting segmented license plate region.

In [45], pre-processing, segmentation and verification are used for number plate localization of car. In the pre-processing the global Thresholding is used to map color intensity into gray scale. In plate's vertical boundary detection stage, Robert's edge operator is used to emphasize vertical edges. The authors assumed two points: plates are oriented horizontally and there is a significant intensity difference between plate background and character foreground. A horizontally oriented rank-filter of size $M \times N$ pixels is moved alongside with the image. Then by using vertical projection is used to detect plate's vertical boundaries. Sometimes the plate is skewed as shown in fig. 2(a). To eliminate skew position in a number plate a Randon Transform (RT) function is used in conjunction with Dirac's delta function. Horizontal boundaries are detected by using series of morphological erosions with horizontally oriented structured elements are applied. Finally two step verification procedure is used. In the first step, the global binarization is done via Otsu's algorithm. The authors assumed dark characters with light background for this purpose. In the second step, the authors compared binarization threshold with the plate intensity median. As per Shapiro et al. probability of detecting number plate is higher when the intensity median of the plate zone is greater than the threshold. After passing all the test number plate is approved successfully. If any of the tests fails then current plate region is rejected and the system goes back to the segmentation stage to search for the another plate region. After maximum number of iteration if system is not able to find plate region then an algorithm is stopped and error message is issued. The average processing time for single image was 0.4s on 3 GHz Pentium processor with a varying distance of 3 to 10m from camera to vehicle.

A dynamic programming based plate segmentation algorithm is proposed in [46]. The authors discussed problem of plate segmentation and provided different approach to solve it. Similar approach is proposed in [47]. The authors used multiple thresholds method to extract candidate regions. The authors used segmented blobs to provide geometric constraints for numeric characters of a number plate. So it is not required use any image features likes edges, colors, or lines. The experiments were carried out on on a desktop computer equipped with an Intel Core-Duo 3.0GHz CPU. The authors used Adaboost [48] algorithm with OpenCV to train. It took 0.5s to detect and locate number plate. The system is mainly used to detect Korean number plate characters.

In [49], a fuzzy discipline based approach is proposed for number plate segmentation. In license plate locating module, the authors considered number plates having colors white, black, red and green. The edge detector algorithm is sensitive to only black-white, red-white and green-white edges. The transformation from RGB to HIS is used based on the formula given in this paper. After that different edge maps are formed, a two stage fuzzy aggregator is used to integrate these maps. After that plate candidates are determined based on the integrated map. By using color edge detector, fuzzy maps and fuzzy aggregation the candidate region is located. Before remitting number plate for further processing binarization, connected component and noise removal is applied to it. The algorithm was executed on Pentium - IV 1.6 GHz PC. It took around 0.4s to locate all the possible license plate regions.

A novel future fusion approach is proposed in [50]. The authors converted color image into gray scale by using multiple thresholds and Otsu's threshold. The authors used different approaches such as deterministic approach: pixel voting, probabilistic approach: global binarization, probabilistic approach: local binarization and combination among these approaches to locate the license plate.

In [51], to detect license plate candidate region verification process is proposed. It consists of verification of lower part, upper part and vertical border.

In [52], a cognitive and video-based approach is proposed. As per Thome et al. license plate detection approach falls in two groups: appearance based and gradient methods. The appearance based approach depends on color or texture feature to separate license plate from background. Gradient based approach is used for high contrast license plate. The authors used gradient-based strategy for license plate detection. Each frame is thus processed to localize areas with a high vertical gradient density. A vertical Sobel mark filter is applied after contour enhancement. The pixels are identified as text or non text area by using final labelling. Then connected component analysis (CCA) is applied on binary map to extract set of N candidates for license plate. The experiment was carried out on Pentium processor with 2.66GHz with 512MB RAM. The software was developed using Microsoft Visual studio 2005 without code optimization. Processing time for license plate detection was 15ms.

An inductive learning RULE-3 based system is proposed in [20]. RULE-3 is a simple algorithm containing several steps for extracting objects having certain attributes. Recognition of number plate contains four steps such as finding edges which are contained in letter, Recognizing the letter using an extracted set of rules, Applying previous steps to all characters contained in the number plate being processed and Recognize number plate by bringing all characters used together.

In [23], fuzzy-based algorithm is applied. To extract license plate region a four step method is implemented. In the first step noise is eliminated from the input image. Edge detection is used in second step of find rectangle area of candidate region. In the third step, based on size, histogram and other information invalid rectangle areas are discarded. In the last step geometric rectification is used to obtain license plate candidate region. As these steps need some addition processing, authors used fuzzy-based algorithm containing several steps to extract license plate with more accuracy. The system was developed on TI DM642 600 MHz/32 MB RAM with C language under CCStudio V3.1 environment. The overall average processing time was ~418.81ms.

Number plate can be detected based on color, edge and other features. An edge-based color-aided method is discussed in [53]. For image enhancement intensity variance and edge density methods are proposed. After applying intensity variance and edge density methods, license plate detection process is executed. The plate detection involves several steps. Vertical edge density estimation is used to avoid missing plate edges due to bad lighting. In the next step a Gaussian mixture is used to emphasize the constancy of intensity values within plate region, along horizontal direction. Then 80% threshold value is used to detect candidate region. Finally morphological processing and color analysis of candidate regions are used to segment license plate. The system was developed using MATLAB on Pentium 3.0 GHz. The overall average processing time was ~1.36s.

A probabilistic neural network (PNN) based approach is presented in [11]. The PNN algorithm works on gray scale image. Bottom-Hat filtering is used to enhance the potential plate regions. To separate the object of interest from background a thresholding is employed for binarization of the gray level image. Because of varying lighting conditions, brightness levels may vary and some adaptation is necessary. To perform it Otsu's Thresholding technique is used as it is adaptive in nature. Each segment of the binary image is labelled according to color of each segment to enable classification. The plate extraction is done calculating the Column Sum Vector (CSV) and its local minima. The algorithm was executed on Intel® Core™2 Duo Processor CPU P8400 (2.26GHz, 2267 MHz). The plate recognition processing time was 0.1s.

In [24], a robust and reliable SIFT based method is used to describe local feature of a number plate. As per Morteza Zahedi et al., the set of features extracted from the training images must be robust to changes in image scale, noise and illumination in order to perform reliable recognition. The more details regarding license plate recognition are not mentioned in this paper.

A MATLAB based system is proposed in [54]. The authors used pre-processing step to convert color image into binary based on the equation presented in this paper. Then by using adaptive median filter, vehicle images gray stretch and vehicle images gradient sharpening a license plate is extracted.

In [28], a trichromatic imaging and color-discrete characteristic approach is used to locate license plate. As per Xing Yang et al. number plates from 105 countries are composed of 11 combinations such as : (1) cyan–black; (2)

cyan–white; (3) black–red; (4) black–white; (5) blue–white; (6) white–red; (7) white–green; (8) yellow–black; (9) yellow–blue; (10) yellow–green; and (11) yellow–red. Based on this information, authors divided six groups of RGB components. Then authors derived several trichromatic functions and a binarized image is obtained. In the next step, de-noising and searching are used to locate license plate finally. The system was Intel Pentium 4, 2.4 GHz, and 1-GB memory. The overall average processing time was 57ms.

Image segmentation techniques such as color texture based [55], coarse-to-fine strategy[56], wrapper based approach[57], content based image retrieval [58], dynamic region merging [59], Dual Multiscale Morphological Reconstructions and Retrieval Applications [37], background recognition and perceptual organization [60], niching particle swarm optimization [61], constraint satisfaction neural network [62], two stage self organizing network [63], adaptive local thresholds [64], vectorial scale-based fuzzy-connected image segmentation [65], mixed deterministic and Monte-Carlo [66], evaluation matrix based image segmentation [67], neutrosophic set and wavelet transformation [36], non linear distance matrix [68], shape-prior based image segmentation with intensity-based image registration [69] and least squares support vector machine (LS-SVM) [70] can be useful for object detection. In [71], survey of different image segmentation techniques is discussed. The authors focused on different unsupervised methods. Some of these methods such as [56], [36] and [70] can be applicable to number plate detection. The method discussed in [56] can be useful to detect multiple objects from the image. It is more suitable for segmentation of multiple vehicle number plates from the traffic image. The work

Table 1. Number plate detection rate and image size

Ref	Image size	Success Rate (in %)	Ref	Image Size	Success Rate (in %)
[5]	1024 X 768	96,5	[43]	40 X 280	Not reported
[33]	640 X 480	Not reported	[44]	**640 X 480**	**Not reported**
[17]	720 X 576 1920 X 1280	90,1	[45]	Not reported	81,20
[34]	Not reported	87	[49]	640 X 480 768 X 512	97,9
[15]	640 X 480	97,3	[47]	692 X 512	97,14(Four Characters)
[13]	**236 X 48**	**Not reported**	[50]	480 X 640	61,36(Pixel voting) 90,65 (Global Thresholding) 78,26 (Local Thresholding) 93,78 (Combination of global and local binarization)
[19]	640 X 480	97,16	[51]	1300 X 1030	92,31
[39]	360 X 288 to 1024 X 768	94	[52]	640 X 480	98,3
[6]	220x50	98,82	[21]	324 X 243	97,6
[14]	648 × 486	96,4	[23]	**720 X 576** **768 X 576**	**Not reported**
[8]	640 X 480	89	[53]	640 X 480	~75,17
[41]	**640 X 480**	**Not reported**	[11]	384 X 288	91
[42]	768 X 256	87,6	[28]	600 X 330 768 X 576	94,7
			[38]	**640 X 480**	**Not reported**
Bold indicates overall success rate is mentioned but number plate detection rate is not mentioned					

presented in [46], [72] lack description and clarity regarding technical details of number plate segmentation algorithm, A Comparative study of image segmentation techniques and object matching using segmentation is well explained in [73].

2.8 Discussion

In most of the literatures, the number plate segmentation algorithms work in restricted conditions like illumination, number plate shape (generally rectangle), size, distance from camera and vehicle and color. It is to be noted that only few algorithms work for real-time video image of a number plate [33], [30],[39], [51], [61], otherwise static image of number plate is remitted to ANPR for further processing. In Table 1, different plate segmentation detection success rate against plate resolution of different ANPR is depicted. The systems in which image size and success rate of number plate detections are not mentioned, are not included in Table 1. It is observed that plate segmentation processing time is ranged from 15ms to 1360ms. The lower processing time of 15ms was reported in [52] while higher processing time of 1360 was reported in [53]. It is evident that number plate detection rate affects character segmentation and character recognition which in turn affects overall recognition rate. Based on the study of several literature presented in this section, it can be concluded that Image binarization, Sliding concentric window (SCW), Sobel operator, Canny-edge operator, Connected component analysis(CCA), Hough Transform (HT), Fuzzy discipline based approach, Probabilistic neural network (PNN) and trichromatic imaging with color-discrete characteristic approach can provide promising result for number plate segmentation.

In order to proceed with character recognition, further image processing in the form of character segmentation is required, which is discussed in the next section.

3. CHARACTER SEGMENTATION

After locating number plate, characters are examined for the further process. As with the plate segmentation there are various methods available for conducting character segmentation. As many methods fall in more than one category it is not possible to do category wise discussion. In this section common related work in this area followed by discussion is discussed. Some methods such as image binarization and CCA are already discussed in Section 2 can also be applied to character segmentation.

3.1 Related work in character segmentation

In [5], the candidate region is cropped in 78 X 228 pixels by using bicubic interpolation and then subjected to SCW for segmentation. The authors used threshold value of 0.7 for optimization of the results. After the character segmentation process, each character is resized to pixel size of 9 X 12.

Prathamesh Kulkarni et al. [34] conclude that blob coloring and peak-to-valley methods are not suitable for Indian number plate. The authors proposed image scissoring algorithm in which a number plate is vertically scanned and scissored at the row where there is no white pixel and this information is stored in the matrix. In case of more than one matrix, a false matrix is discarded based on the formula given in this paper. Same process is repeated for horizontal direction by taking width as a threshold.

CCA is very useful technique for processing binary image. In [19] horizontal and vertical correction and image enhancement are performed as pre-processing steps for character segmentation. CCA is used in horizontal and vertical correction. After performing these steps plate is transformed to black characters / white background and then resized to 100 X 200. Then all the characters are segmented to the unique size of 32 X 32. In [44] image binarization and connected component labelling methods are used

In [16], three matrices are used to storing plate location and binarization, number of columns in BW and number of row in BW respectively. Then after precise location of top and bottom boundaries are detected, which are followed by vertical projection and Thresholding to segment the characters.

H.Erdinc Kocer [6] used contrast extension, median filtering and blob coloring methods for character segmentation. Contrast extension is used to make image sharp. As per H.Erdinc Kocer the histogram equalization is a popular technique to improve the appearance of a poor contrasted image. In median filtering unwanted noisy regions are removed. Blob coloring method is applied to binary image to detect closed and contact less regions. In this method, an L shaped template is used to scan image from left to right and top to bottom. This scanning process is used to determine the independent regions by obtaining the connections into four directions from zero valued background. The four directional blob coloring algorithm is applied to the binary coding license plate image for extracting the characters. At the end of this process the numbers are segmented in the size of 28 X 35 and letters are segmented in the size of 30 X 40. Another algorithm based on blob detection is proposed in [14]. The character segmentation process consists of character height estimation, character width estimation and blob extraction. Character height estimation contains three parts: color reverse, vertical edge detection and horizontal projection histogram. Color reverse is used to make color of license plate characters as black by using statistical analysis of edges. Vertical edge detection is used to detect finalized number plate. Sobel mask and image binarization algorithms are used to perform it. Horizontal projection histogram is used to find top and bottom boundary of a character. The distance between upper and lower boundaries is considered as height of a character. Character width estimation contains: image binarization and vertical projection histogram. Image binarization is used to make color as black and white. Vertical projection is used to find gaps between characters. The process is similar as horizontal projection. Blob extraction is a two- step procedure including Blob detection and blob checking algorithms. The blob detection algorithm is an extension of CCA. Blob checking is used to remove non blob characters from the segmented characters.

In [45], character clipper is used to separate character in rectangle box. Then by using feature extractor, classifier, post processor and training phases each character is segmented.

In [25], an improved projection method (IPM) is proposed. The authors mentioned a three step procedure for character segmentation. In first step horizontal, vertical and compound tilts are corrected. Then in second steps auxiliary lines are drawn in between first and last character to detected connected boundaries. In the final step the characters are segmented after removing noise. The experiment was carried out using MATLAB 6.5 using VC++ 6.0.

As per Thome, Nicolas et al. [52] connected component labelling is accurate but might result in failure because of single mis-labelled pixel error. The authors also concluded that histogram projection is more robust but it is less accurate. They used connected component labelling method to preliminary set of contours.

Vertical and horizontal histogram methods are used in [11]. To determine the boundaries of characters, column sum vectors are used. Based on the algorithm two adjacent characters are separated in two.

3.2 Discussion

Character segmentation is very important in order to perform character recognition with good amount of accuracy. Sometimes character recognition is not possible due to error in character segmentation. In some literature of ANPR, character segmentation is not discussed with details. Some methods such as image binarization, CCA, vertical and horizontal projection can produce better results of character segmentation.

4. CHARACTER RECOGNITION

As discussed in Section 2, character recognition helps in identifying and converting image text into editable text. As most of the number plate recognition algorithms use single method for character recognition. In this section, each method is explained.

4.1 Artificial Neural Network (ANN)

Artificial Neural Network (ANN) sometimes known as neural network is a mathematical term, which contains interconnected artificial neurons. Several algorithms such as [5], [6], [7], [8], [18], [52], [11], [10] are based on ANN. In [5] two layer probabilistic neural network with the topology of 180-180-36. The character recognition process was performed in 128ms. In [6] multi layered perceptron (MLP) ANN model is used for classification of characters. In contains input layer for decision making, hidden layer to compute more complicated associations and output layer for resulting decision. Feed forward back-propagation (BP) algorithm was used to train ANN. BP neural network based systems are proposed in [8], [18], [10] with the processing time of 0.06s, in [27]. In [46], HNN is applied to reduce ambiguity between the similar characters e.g. 8 and B, 2 and Z etc. The authors claim to have more than 99% recognition rate.

4.2 Template matching

Template matching is useful for recognition of fixed sized characters. It can be also used for detection of objects generally in face detection and medical image processing. It is further divided in two parts: feature based matching and template based matching. Feature based approach is useful when template image has strong features otherwise template based approach can be useful. In [34] statistical feature extraction method is applied for achieving 85% of character recognition rate. In [15], several features and extracted and salient is computed based on training characters. A linear normalization algorithm is used to adjust all characters with uniform size. The recognition rate of 95.7% is achieved among 1176 images. An SVM based approach is used for feature extraction of Chinese, Kana and English, Numeric characters. The authors achieved success rate of 99.5%, 98.6%, and 97.8% for numerals, Kana, and address recognition respectively. A template based approach is proposed in [16]. The authors used low-resolution template matching method to work with lower resolution image such as 4 X 8. The authors used similarity function to measure similarity between patterns.

4.3 Other methods

In some algorithms character recognition is done by the available Optical Character Recognition (OCR) tool. There are numerous software available for OCR processing. One of the open source OCR tools with multilingual supported is Tesseract [74], [75], which is maintained by Google and available at [76]. It is used in [14] for character recognition. The author modified it to achieve 98.7% of character recognition rate. In [43] authors model extraction of characters as Markov Random Fields (MRF) where the randomness is used to model the uncertainty in the assignment of the pixels. Character extraction is done as the optimization problem based on prior knowledge to maximize a posteriori probability. Then a greedy mutation operator is used to reduce computation cost. The method proposed in [49] consists of three steps: character categorization, topological sorting and self organizing (SO) recognition. Character categorization is used to classify character as alphabet or number. In second step topological features of input character are computed and compared with already stored character templates. Compatible templates will form a test set, in which the character template that best matches the input character is determined. The template test is performed by a SO character recognition method Self-organized neural network is based on Kohonen's self-organized feature maps to handle noisy, broken, or incomplete characters. To differentiate the similar characters from character pairs such as (8, B) and (O, D) the authors predefined an ambiguity set containing the characters 0, 8, B and D. For each character in the set, the non-ambiguous parts of the character are specified as it is shown in fig. 3. After the unknown character is classified as one of the characters in the ambiguity set, a minor comparison between the unknown character and the classed character is performed. Then in the comparison process only non ambiguous parts of characters are focused. The authors achieved recognition rate of 95.6% for the upright license plate images. In [77] a survey on automatic character recognition method is discussed. As per Anju K Sadasivan and T.Senthilkumar [77] the main challenge in character recognition is to handle unknown text layout, different font sizes, different illumination conditions, reflections, shadowing and aliasing.

4.4 Discussion

Fig.3. Distinguishing parts of ambiguous characters in [49].

As character segmentation is the pre-processing steps of character recognition, the recognizer system should be able to handle ambiguous, noisy or distorted characters received from character segmentation phase. Good results are reported with ANN and self organizing (SO) recognition. The details are summarized in Table 2. As OCR is widely used and popular method recently, ANPR developers are focusing on improving accuracy of OCR rather than to redesign the entire ANPR from the scratch. As it is discussed in previous section, some developers are using open source OCR such as Tesseract and modifying it for better accuracy.

Table 2. Character recognition rate with method and type of category

Ref	Method	Success Rate (in %)	Type of Category
[5]	Two layer PNN	89,1	Letters
[34]	Statistical feature extraction.	85	Not reported
[15]	Feature salient	95,7	Not reported
[19]	SVM Integration with feature extraction	93,7	English characters, Chinese, Numeral, Kana
[16]	Template matching	Not reported	Letters, digits
[6]	multi layered perceptron (MLP) ANN	98,17	Letters, digits
[7]	multi layered perceptron (MLP) ANN	Not reported	Letters, digits
[14]	Open source OCR Tesseract	98,7	Letters, digits
[8]	BP neural network	Not reported	Korean Letters, digits
[18]	BP neural network	Not reported	Chinese letters, English letters and digits
[43]	MRF	Not reported	Letters, digits
[49]	character categorization, topological sorting, and self-organizing (SO) recognition	95,6	Letters, digits
[52]	Hierarchical Neural Network(HNN)	95,2	Letters, digits
[11]	PNN	96,5	Letters, digits
[10]	BP neural network	93,5	Letters, digits

5. CONCLUSION

5.1 Future work

ANPR can be further exploited for vehicle owner identification, vehicle model identification traffic control, vehicle speed control and vehicle location tracking. It can be further extended as multilingual ANPR to identify the language of characters automatically based on the training data It can provide various benefits like traffic safety enforcement, security- in case of suspicious activity by vehicle, easy to use, immediate information availability- as compare to searching vehicle owner registration details manually and cost effective for any country For low resolution images some improvement algorithms like super resolution [30], [31] of images should be focused. Most of the ANPR focus on processing one vehicle number plate but in real-time there can be more than one vehicle number plates while the images are being captured. In [5] multiple vehicle number plate images are considered for ANPR while in most of other systems offline images of vehicle, taken from online database such as [78] are given as input to ANPR so the exact results may deviate from the results shown in Table 1 and Table 2. To segment multiple vehicle number plates a coarse-to-fine strategy [56] could be helpful.

Table 3. Different ANPR systems with country supported

Ref	Country(In which ANPR is applied)
[5]	European
[17]	USA, China, Singapore, Australia, South Africa
[34]	India
[15],[35],[18],[23], [22],[40]	China
[7]	Nigeria, Cyprus, Denmark, Germany, Estonia, Finland, France, India, Norway, Slovakia, Portugal, U.S.A, Bulgaria, Czech Republic
[44]	Dutch
[45]	Israel, Bulgaria
[47],[26],[51]	Korea
[52]	Multi-country
[20]	Turkey
[21]	Australia
[53],[24]	Iran
[27]	USA
[28]	China and 104 Countries

5.2 Summary

It is quite clear that A]NPR is difficult system because of different number of phases and presently it is not possible to achieve 100% overall accuracy as each phase is dependent on previous phase. Certain factors like different illumination conditions, vehicle shadow and non-uniform size of license plate characters, different font and background color affect the performance of ANPR. Some systems work in these restricted conditions only and might not produce good amount of accuracy in adverse conditions. Some of the systems are developed and used for specific country, which is summarized in table 3. The systems in which there is no mention of country are not included in table 3. As per table 3, it is evident that very few of the ANPR [34], [7] are developed for India. So there is a wide scope to develop such system for the country like India.

This paper provides comprehensive study of recent development and future trends in ANPR, which can be helpful to the researchers who are involved in such developments.

6. ACKNOWLEDGMENTS

The authors thank Mr. Dharmendra Patel for providing necessary guidance in conducting this research. The authors also thank Charotar University of Science and Technology (CHARUSAT) for providing necessary resources for conducting this survey.

7. REFERENCES

[1] You-Shyang Chen and Ching-Hsue Cheng, "A Delphi-based rough sets fusion model for extracting payment rules of vehicle license tax in the government sector," *Expert Systems with Applications*, vol. 37, no. 3, pp. 2161-2174, 2010.

[2] Anton Satria Prabuwono and Ariff Idris, "A Study of Car Park Control System Using Optical Character Recognition ," in *International Conference on Computer and Electrical Engineering*, 2008, pp. 866-870.

[3] A Albiol, L Sanchis, and J.M Mossi, "Detection of Parked Vehicles Using Spatiotemporal Maps," *IEEE Transactions on Intelligent Transportation Systems*, vol. 12, no. 4, pp. 1277-1291, 2011.

[4] Christos Nikolaos E. Anagnostopoulos, Ioannis E. Anagnostopoulos, Ioannis D. Psoroulas, Vassili Loumos, and Eleftherios Kayafas, *License Plate Recognition From Still Images and Video Sequences: A Survey*, vol. 9, no. 3, pp. 377-391, 2008.

[5] Christos Nikolaos E. Anagnostopoulos, Ioannis E. Anagnostopoulos, Vassili Loumos, and Eleftherios Kayafas, "A License Plate-Recognition Algorithm for Intelligent Transportation System Applications," pp. 377-392, 2006.

[6] H. Erdinc Kocer and K. Kursat Cevik, "Artificial neural netwokrs based vehicle license plate recognition," *Procedia Computer Science*, vol. 3, pp. 1033-1037, 2011.

[7] A Roy and D.P Ghoshal, "Number Plate Recognition for use in different countries using an improved segmenation," in *2nd National Conference on Emerging Trends and Applications in Computer Science(NCETACS)*, 2011, pp. 1-5.

[8] Kaushik Deb, Ibrahim Kahn, Anik Saha, and Kang-Hyun Jo, "An Efficeint Method of Vehicle License Plate Recognition Based on Sliding Concentric Windows and Artificial Neural Network," *Procedia Technology*, vol. 4, pp. 812-819, 2012.

[9] Lucjan Janowski et al., "Quality assessment for a visual and automatic license plate recognition," *Multimedia Tools and Applications Springer US*, pp. 1-18, 2012.

[10] Yifan Zhu, Han Huang, Zhenyu Xu, Yiyu He, and Shiqiu Liu, "Chinese-style Plate Recognition Based on Artificaial Neural Network and Statistics," *Procedia Engineering*, vol. 15, pp. 3556-3561, 2011.

[11] Fikriye Öztürk and Figen Özen, "A New License Plate Recognition System Based on Probabilistic Neural Networks," *Procedia Technology*, vol. 1, pp. 124-128, 2012.

[12] Jian Liang, D Dementhon, and D Doermann, "Geometric Rectification of Camera- Captured Document Images," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 9, no. 3, pp. 591-605, 2008.

[13] Xin Fan and Guoliang Fan, "Graphical Models for Joint Segmentation and Recognition of License Plate Characters," *IEEE Signal Processing Letters*, vol. 16, no. 1, pp. 10-13, 2009.

[14] Lihong Zheng, Xiangjian He, Bijan Samali, and Laurence T. Yang, "An algorithm for accuracy enhancement of

license recognition," *Journal of Computer and System Sciences*, , 2012.

[15] Zhen-Xue Chen, Cheng-Yun Liu, Fa-Liang Chang, and Guo-You Wang, "Automatic License-Plate Location and Recognition Based on Feature Saliance," *IEEE Transactions on Vehicular Technology*, vol. 58, no. 7, pp. 3781-3785, 2009.

[16] Ch.Jaya Lakshmi, Dr.A.Jhansi Rani, Dr.K.Sri Ramakrishna, and M. KantiKiran, "A Novel Approach for Indian License Recognition System," *International Journal of Advanced Engineering Sciences and Technologies*, vol. 6, no. 1, pp. 10-14, 2011.

[17] Jianbin Jiao, Qixiang Ye, and Qingming Huang, "A configurabe method for multi-style license plate recognition," *Pattern Recognition*, vol. 42, no. 3, pp. 358-369, 2009.

[18] Zhigang Zhang and Cong Wang, "The Reseach of Vehicle Plate Recogniton Technical Based on BP Neural Network," *AASRI Procedia*, vol. 1, pp. 74-81, 2012.

[19] Ying Wen et al., "An Algorithm for License Plate recognition Applied to Intelligent Transportation System," *IEEE Transactions of Intelligent Transportation Systems*, pp. 1-16, 2011.

[20] Mehmet Sabih Aksoy and Ahmet Kürsat Türker Gültekin Çagıl, "Number-plate recognition using inductive learning," *Robotics and Autonomous Systems*, vol. 33, no. 2-3, pp. 149-153, 2000.

[21] Wenjing Jia, Huaifeng Zhang, and Xiangjian He, "Region-based license plate detection," *Journal of Network and Computer Applications*, vol. 30, no. 4, pp. 1324-1333, November 2007.

[22] Yang Yang, Xuhui Gao, and Guowei Yang, "Study the Method of Vehicle License Locating Based on Color Segmentation," *Procedia Engineering* , vol. 15, pp. 1324-1329, 2011.

[23] Feng Wang et al., "Fuzzy-based algorithm for color recognition of license plates," *Pattern Recognition Letters*, vol. 29, no. 7, pp. 1007-1020, May 2008.

[24] Morteza Zahedi and Seyed Mahdi Salehi, "License plate recognition system based on SIFT features," *Procedia Computer Science*, vol. 3, pp. 998-1002, 2011.

[25] Mei-Sen Pan, Jun-Biao Yan, and Zheng-Hong Xiao, "Vehicle license plate character segmentation ," *Intenational Journal of Automation and Computing*, pp. 425-432, 2008.

[26] Kaushik Deb, Andrey Vavilin, Jung-Won Kim, and Kang-Hyun Jo, "Vehicle license plate tilt correction based on the straight lne fitting method and minimizing variance of coordinates of projection point," *International Journal of Control, Automation and Systems.*, pp. 975-984, 2010.

[27] Francisco Moraes Oliveira-Neto, Lee D. Han, and Myong K Jeong, "Online license plate matching procedures using license-plate recognition machine and new weighted edit distance," *Transportation Research Part C: Emerging Technologies*, vol. 21, no. 1, pp. 306-320, April 2012.

[28] Xing Yang, Xiao-Li Hao, and Gang Zhao, "License plate location based on trichromatic imaging and color-discrete characteristic," *Optik- International Journal for Light and Electron Optics*, vol. 123, no. 16, pp. 1486-1491, August 2012.

[29] Cynthia Lum, Julie Hibdon, Breanne Cave, Christopher S. Koper, and Linda Merola, "License plate reader(LRP) police patrols in crime hot spots: an experimental evaluation in two adjacent jurisdictionss," *Journal of Experimel Criminology, Springer Netherlands*, , pp. 321-345, 2011.

[30] K.V. Suresh, G. Mahesh Kumar, and A.N. Rajagopalan, "Superresolution of license plates in real traffic videos," *IEEE Trans. Intell. Transp. Syst*, vol. 8, no. 2, pp. 321-331, 2007.

[31] Yushuang Tian, Kim-Hui Yap, and Yu He, "Vehicle license plate super-resolution using soft learning prior," *Multimedia Tools and Applications, Springer US*, pp. 519-535, 2012.

[32] D.H. Ballard, "Generalizing the Hough Transform to Detect Arbitary Shapes," *Pattern Recognition*, vol. 13, no. 2, pp. 111-122, 1981.

[33] Shen-Zheng Wang and Hsi-Jian Lee, "A cascade framework for real-time statistical plate recognition system," *IEEE Trans. Inf. Forensics security*, vol. 2, no. 2, pp. 267-282, 2007.

[34] Prathamesh Kulkarni, Ashish Khatri, Prateek Banga, and Kushal Shah, "Automatic Number Plate Recognition (ANPR)," in *RADIOELEKTRONIKA. 19th International Conference*, 2009.

[35] Hui Wu and Bing Li, "License Plate Recognition System," in *International Conference on Multimedia Technology (ICMT)*, 2011, pp. 5425-5427.

[36] Abdulkar Sengur and Yanhui Guo, "Color texture image segmentation based on neutrosophic set and wavelet transformation ," *Computer Vision and Image Understanding*, vol. 115, no. 8, pp. 1134-1144, August 2011.

[37] Jiann-Jone Chen, Chun-Rong Su, W.E.L Grimson, Jun-Lin Liu, and De-Hui Shiue, "Object Segmentation of Database Images by Dual Multiscale Morphological Reconstructions and Retrieval Applications," *IEEE Transactions on Image Processing*, vol. 21, no. 2, pp. 828-843, 2012.

[38] Mahmood Ashoori Lalimi, Sedigheh Ghofrani, and Des McLernon, "A vehicle license plate detection method using region and edge based methods," *Computers & Electrical Engineering*, November 2012.

[39] M. S. Sarfraz et al., "Real-Time automatic license plate recognition for CCTV forensic applications," *Journal of Real-Time Image Processing- Springer Berlin/Heidelberg*, 2011.

[40] Rongbao Chen and Yunfei Luo, "An Improved License Plate Location Method Based On Edge Detection," *Physics Procedia*, vol. 24, pp. 1350-1356, 2012.

[41] T Naito, T Tsukada, K Kozuka, and S yamamoto, "Robust license-plate recognition method for passing vehicles under outside environment," *IEEE Transactions on Vehicular Technology*, vol. 49, no. 6, pp. 2309-2319, 2000.

[42] R Zunino and S Rovetta, "Vector quantization for license-plate location and image coding," *IEEE Transactions on Industrial Electornics*, vol. 47, no. 1, pp. 159-167, 2000.

[43] Yuntao Cui and Qian Huang, "Extracting character of license pltes from video sApplicationsequences," *Machine Vision and Applications, Springer Verlag*, p. 308, 1998.

[44] M.H Ter Brugge, J.A.g jhuis, L Spaanenburg, and J.H Stevens, "CNN- Applications in Toll Driving," *Journal of VLSI signal processing systems for signal, image and video tehnology*, pp. 465-477, 1999.

[45] Vladimir Shapiro and Georgi Gluhchev Dimo Dimov, "Towards a Multinational Car License Plate Recognition system," *Machine Vision and Appplcations, Springer-Verlag*, pp. 173-183, 2006.

[46] E.N Vesnin and V.A Tsarev, "Segmentation of images of license plates," *Pattern Recogniton and Image Analysis*, pp. 108-110, 2006.

[47] A Kang, D. J;, "Dynamic programming -based method for extraction of license numbers of speeding vehicles on the highway ," *International Journal of Automotive Technology*, pp. 205-210, 2009.

[48] P. Viola and M JOnes, "Robust real-time face detection," *Int. J. Comput. Vis*, vol. 57, no. 2, pp. 137-154, 2004.

[49] Shyang-Lih Chang, Li-Shien Chen, Yun-Chung Chung, and Sei-Wan Chen, "Automatic license plate recogniton," *IEEE Transactions on Intelligent Transportation Systems*, vol. 5, no. 1, pp. 42-53, 2004.

[50] Rami Al-Hmouz and Subhash Challa, "License plate location based on a probabilistic model," *Machin Vision and Applications, Springer-Verlag*, pp. 319-330, 2010.

[51] J. K. Chang, Ryoo Seungteak, and Heuiseok Lim, "Real-time vehicle tracking mechanism with license plate recognition from reoad images," *The journal of super computing* , pp. 1-12, 2011.

[52] Nicolas Thome, Antoine Vacavant, Lionel Robinault, and Serge Miguet, "A cognitive and video-based approach for multinational License Plate Recognition ," *Machine Vision and Applications, Springer-Verlag*, pp. 389-407, 2011.

[53] Vahid Abolghasemi and Alireza Ahmadyfard, "An edge-based color aided method for license plate detection," *Image and Vision Computing* , vol. 27, no. 8, pp. 1134-1142, July 2009.

[54] Xiaofeng Zhang, Fengchang Xu, and Yan Su, "Research on the Licnese Plate Recognition based on MATLAB," *Procedia Engineering*, vol. 15, pp. 1330-1334, 2011.

[55] M. Mirmehdi and M Petrou, "Segmentation of color textures," *IEEE Transactions of Pattern Analysis and Machine Intelligence*, vol. 22, no. 2, pp. 142-159, 2000.

[56] Y. Amit, D. German, and X. Fan, "A coarse-to-fine strategy for multiclass shape detection," *IEEE Trans. Patttern Anal. Mach. Intell*, vol. 26, no. 12, pp. 1606-1621, 2004.

[57] M.E Farmer and A.k Jain, "A wrapper based approach to image segmentatin and classification," *IEEE Transaction on Image Processing*, vol. 14, no. 12, pp. 2060-2072, 2005.

[58] Dewen Zhuang and Shoujue Wang, "Content-Based Image Retrieval Based on Integrating Region Segmentation and Relevance Feedback," in *International Conference on Multimedia Technology (ICMT)*, 2010, pp. 1-3.

[59] Bo Peng, Lei Zhang, and D Zhang, "Automatic Image Segmenation by Dynamic Region Merging," *IEEE Transactions on Image Processing*, vol. 20, no. 12, pp. 3592-3605, 2011.

[60] Cheng, Chang; Koschan, A; Chen, Chung-Hao; Page, D.L; Abidi, M.A, "Outdoor Scene Image Segmentation Based on Background Recognition and Perceptual Organization," *IEEE Transactions on Image Processing*, vol. 21, no. 3, pp. 1007-1019, 2012.

[61] Shahid Mehmood, Stefano Cagnoni, Monica Mordonini, and Shoab Ahmad Khan, "An embeded architecture for real-time object detection in digital images based on niching particle swarm optimization," *Journal of Real-Time Image Processing, Springer-Verlag*, pp. 1-15, 2012.

[62] Fatih Kurugollu, Bülent Sankur, and A. Emre Harmanci, "Image segmentation by relaxation using constraint satisfaction neural network," *Image and Vision Computing*, vol. 20, no. 7, pp. 483-497, May 2002.

[63] S.H. Ong, N.C. Yeo, K.H Lee, Y. V. Venkatesh, and D.M. Cao, "Segmentation of color images using a two-stage self-organizing network," *Image and Vision Computing*, vol. 20, no. 4, pp. 279-289, 2002.

[64] Ety Navon, Ofer Miller, and Amir Averbuch, "Color Image segmentation based on adaptive local thresholds," *Image and Vision Computing*, vol. 23, no. 1, pp. 69-85, January 2005.

[65] Ying Zhuge, Jayaram K. Udupa, and Punam K. Saha, "Vector scale-based fuzzy-connected image segmentation," *Computer Vision and Image Understanding*, vol. 110, no. 2, pp. 177-193, March 2006.

[66] Daniel Crevier, "Image segmentation algorithm development using ground truth image data sets," *Computer Vision and Image Understanding*, vol. 112, no. 2, pp. 143-159, November 2008.

[67] Mark Polak, Hong Zhang, and Minghong Pi, "An evaluation metric for image segmentation of multiple objects," *Image and Vision Computing* , vol. 27, no. 8, pp. 1223-1227, July 2009.

[68] Antonio Carlos Sobiernaski, Eros Comunello, and Ald von Wangenheim, "Leaning a nonlinear distance metric for supervised region-merging image segmentation," *Computer Vision and Image Understanding*, vol. 115, no. 2, pp. 127-139, February 2011.

[69] Siqi Chen, Daniel Cremers, and Richard J. Radke, "Image segmentation with one shape prior - A template-based formulation," *Image and Vision Computing* , vol. 30, no. 12, pp. 1032-1042, December 2012.

[70] Hong-Ying Yang, Xiang-Yang, Qin-Yan Wang, and Xian-Jin Zhang, "LS-SVM based image segmentation using color and texture information ," *Journal of Visual*

Communication and Image Representation , vol. 23, no. 7, pp. 1095-1112, October 2012.

[71] Hui Zhang, Jason E. Fritts, and Sally A. Goldman, "Image Segmentation evaluation: A survey of unsupervised methods," *Computer Vision and Image Understanding*, vol. 110, no. 2, pp. 260-280, May 2008.

[72] J. Phelawan, P. Kittisut, and N. Pornsuwancharoen, "A new technique for distance measurement of between vehicles to vehicles by plate car using image processing," *Procedia Engineering*, vol. 32, pp. 348-353, 2012.

[73] S Sapna Varshney, N Rajpal, and R Purwar, "Comparative Study of image segmentation techniques and object matching using segmentation," in *International Conference on Methods adn Models in Computer Science*, 2009, pp. 1-6.

[74] Smith R, "An Overview of the Tesseract OCR Engine," in *IEEE Ninth Intenational Conference Proceeding of Document anay and Recognition*, 2007.

[75] Chirag Patel, Atul Patel, and Dharmendra Patel, "Optical Character Recognition by Open source OCR Tool Tesseract : A Case Study," *International Journal of Computer Applications, Foundation of Computer Science, New York. USA*, vol. 55, no. 10, pp. 50-56, October 2012.

[76] Google Code. [Online] (2012). http://code.google.com/p/tesseract-ocr

[77] Anju K. Sadasivan and T. Senthilkumar, "Automatic Character Recognition in Complex Images," *Procedia Engineering*, vol. 30, pp. 218-225, 2012.

[78] Jerome Connix, License Plate Mania. [Online]. http://www.licenseplatemania.com

AUTHOR'S PROFILE

Chirag Patel received Bachelor degree in computer applications (B.C.A) degree from Dharmsinh Desai University Nadiad, Gujarat, India in 2002 and Masters Degree in Computer Applications (M.C.A) from Gujarat University, Gujarat, India in 2005. He is pursuing PhD in Computer Science and Applications from Charotar University of Science and Technology (CHARUSAT). He is with MCA Department at Smt Chandaben Mohanbhai Patel Institute of Computer Applications, Charotar University of Science and Technology (CHARUSAT), Changa, Gujarat, India. His research interests include Information Retrieval from image/video, Image Processing and Service Oriented Architecture.

Dr. Dipti Shah received Bachelor degree in Science; B.Sc.(Maths), M.C.A. Degree from S.P. University , Gujarat, India. She has also received Ph.D in Computer Science, degree from S.P. University, Gujarat, India. Now she is Professor at G.H.Patel Department of Computer Science, S.P. University, Anand, Gujarat, India. Her Research interests include Computer Graphics, Image Processing, Multimedia and Medical Informatics.

Dr. Atul Patel received Bachelor in Science B.Sc (Electronics), M.C.A. Degree from Gujarat University, India. M.Phil. (Computer Science) Degree from Madurai Kamraj University, India. He has received his Ph.D degree from S. P. University.Now he is an Associate Professor and Head, Smt Chandaben Mohanbhai Patel Institute of Computer Applications – Changa, India. His main research areas are wireless communication and Network Security