A Detailed Comparative Analysis of Automatic License Plate Recognition Techniques

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Abstract : Automatic License Plate Recognition (ALPR) is an application of Optical Character Recognition (OCR) in Digital Image Processing domain. ALPR has numerous commercial applications like Smart Traffic Monitoring System, Automated Toll Collection, Security System across Borders and Parking Lots, Highway Traffic Control and similar Transport Surveillance facilities. Extensive research has been carried out and promising results has been achieved as well. This review paper aims towards the study of ALPR as a systematic process and to compare work done in this direction done so far.

Index Terms **- License Plate, OCR, Segmentation, Feature Extraction, Classification, Recognition.**

I. INTRODUCTION

First license plate was provided by German police in 1899 to Mr. C. Barthes and the first ALPR was developed by UK police in 1979 [19]. Now a day, ALPR is the most important method to develop Intelligent Traffic Surveillance System [1][6]. It plays an important role in automated transportation system. It has a number of applications based on different technological aspects like it detects and recognizes a license plate from an image captured by a camera [2]- [6] [10]- [12] [14] [29] [30]- [34] or it can track a vehicle from video input from a recorded database, find respective frame and then identify license plate [1] [17] [23] [28]. ALPR is a multiparameter, multistage process and the efficiency of system depends on various technical and environmental constraints. There are a number of challenges related to accurate analysis of license plate detection and correction like scene complexity, unknown light conditions, skewness, blurring, broken character, aspect ratio, font style, multilingual environment as discussed in [5] [16] [20] [27]. In [35] a robust system is designed taking in consideration the applied rotation of license plate up to some extent. In [33] an algorithm sequence able to cope with plates of different sizes and positions. Also in [29] more than one license plate is segmented present in a single image. [17] has discussed performance of an ALPR system depending on external factors like day and night time, rainy, foggy and clear weather condition. Figure 1.1 shows the basic steps of an ALPR system.

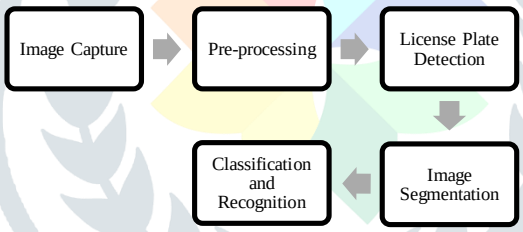

Figure1.1: Procedural steps involved in ALPR system

An ALPR system consists of technological procedures that are application and environment specific [6][7][8] [13]. Following are the basic steps involved in ALPR: (1) Image Capture (2) Pre-processing (3) License Plate Detection/Localization (4) Image Segmentation (5) Classification (6) Recognition. Next sections of paper are dedicated to step-to-step comparative analysis of ALPR process.

II. LITERATURE STUDY

1.1 Image Capture

Image acquisition or image capturing is the very first step in license plate recognition. Image of a license plate is captured using a camera. The resolution of camera used is a deciding factor in accurate recognition. A high quality image ensures better detection output while a low quality image may result in wrong recognition or false detection of plate features. Image may be obtained from a CCD camera as in [29]. Based on input device the recognition process can be classified as online or offline process [1]. Online process uses real time data and are employed in automated recognition systems that are associated with respective database and are used in commercial way like smart toll collection. Offline process doesn't require real time data and use already captured images [2][3][6] [10] [14] [29] [31] [32] [34]. Video based ALPR system use frame selection procedure so that only frames containing license plate are selected for further processing [1].

1.2 Pre-processing

Pre-processing involves the image modifying operations that are performed on any digital image so that it becomes more suitable for further processing. Pre-processing steps may involve some very simple operation like smoothing sharpening or may involve complex algorithms as per requirement. In [12] [15] [35] image enhancement using Histogram is used for improvement and brightness control. For better detection contour enhancement has been done in [28]. Pre-processing also deals with various plate variations while designing an unconstrained or multinational plate detection [23] [28]. Here in such case anyone or more than one operations may be desired from Binarization, Noise reduction, skew correction, morphological operations, theresholding, thinning and skeletonisation [8][9] [27] [28]. Pre-processing also deals with plate variations like location, size, color, font, occlusion, inclination etc. [26] [33].

Not only physical variations, a robust and potential ALPR system also deals with plate detection under different environmental variations like illumination and background. Dealing with this issue [23] uses illumination compensation concept in pre-processing of image before detection. Super resolution and theresholding provides fair results when used in case of video input data [6].

1.3 Plate Detection or Plate Localization

The image obtained after pre-processing is nearly ideal to extract license plate or we can say to locate license plate. The most basic way to find license plate in a given image is boundary or edge detection. Prior to this, the image is converted in to grey scale image in order to enhance plate details among background pixels [1] [44] [45]. If a colour edge detection or colour texture technique is to be used, then RGB image can be used as it is after pre-processing [34] [26] [46]. Another hybrid boundary and edge detection algorithm and global image information based localization techniques also provide comparative results [15] [19] [24]. In [17] single frame ALPR, License plate tracking, and In-track Clustering Correction(ITCC) are implemented and compared.

In another work local normalization with Optimal Adaptive Correlation (OAC) technique is used automatically detect the license plates on video sequence [23]. Other applicable techniques to detect license plate from image or video are appearance based or gradient based approach [28]. Horizontal and vertical edge detection or boundary detection is also an effective plate detection approach [15] [19]. With the advancement in artificial intelligence (AI), fuzzy maps [34] and Neural Network based algorithms are used like Back Propagation Neural Network (BPNN) [2], Pulse Coupled Neural Network (PCNN), Time Delay Neural Network (TDNN), Discrete Time Cellular Neural Network (DTCNN) [48]- [50], Convolutional Neural Network [3] [6] [10]. AI based system involve efficient learning methods which further makes system more efficient and fast responsive.

While using simple edge detection may provide false detection due to similar pattern over vehicle surface, combining edge detection with mathematical morphology model helps improving efficiency. [26] [39]- [42]. Genetic Algorithm is found to obtain better detection in video inputs as discussed in [53]. Canny edge detection and blob colouring algorithm is used in [29]. Hough Transformation has been employed by [4] [13] [38] [54] for better results. Feature based number plate localization is helpful when the image obtained is degraded one [30]. When background features try to shade license plate boundary or edges, it is found that region based hybrid detection techniques solve the problem [26] [32]. [43] uses block based processing for plate detection. Wavelet transformation is also a useful tool in this process as shown by [14] [47]. Vector Quantization as studied by [51] is a very significant technique as it supports picture compression making it suitable for storage and effectively localize the license plate as well.

1.4 Image Segmentation

Image segmentation process is employed so that the information can be extracted from the image for recognition purpose. Line segmentation can be used using horizontal projection profile and character segmentation is performed using vertical projection [1]. Segmentation helps in studying and extracting very crucial features like lines, corners, curves etc. Such information makes character recognition very efficient and fast [34]. Different Plate Patterns and alignment need different type of segmentation algorithm to be employed.

Depending upon type of image top-down, bottom-up or hybrid approach can be used [11] [27]. In top-down approach image is segmented in to small subsets and further inherent subsets while in bottom-up approach image is broken I to smallest unit and then sets of subsets are made. Hybrid technique uses both on local basis. Image scissoring is employed in [30] for segmentation. To reduce processing time and make system faster Sliding Concentric Window technique is suggested in [20]. Super resolution and adaptive thresholding has been implemented in [33] while local binarization and Markov Random Field has also found to be effective solution in segmentation context [10] [13] [53] [55]. In another work, Feature vector extraction and mathematical morphology is used [52].

1.5 Classification and Feature Extraction

Classification and feature extraction process are used to extract information from segmented image. According to segmentation approach, information can be extracted on local or region specific or on global basis. AI based classifiers include Neural Network (NN) classifiers [18] [37]. [36] uses a binary tree classifier in 4 layered feedforward manner. In another work, Mahalanobis classification is used [32]. Cross correlation based and D-Isomap based classification approach is suggested in [23], while hybrid techniques that combine pixel connectivity, projection profiles, histogram and morphological features has been studied in [56].

With innovative and advanced development in Machine Learning has shown highly efficient results used in [5] [10] through Deep Learning (DL). Also, zoning, moments, template matching, global transformation and series expansion methods are compared in [24].

Feature extraction is done using Directional Histogram method [37], while feature extraction both global and local are performed in [36]. Here middle line, concave, width, point etc. are local features. In [27] statistical and structure feature are extracted specifically to recognize image.

1.6 Image Recognition

Image Recognition is the final step in ALPR system. It is a very significant and decisive phase and the efficiency and accuracy of system depends on this process. There are a number of pattern or character recognition methods available to be employed. Image recognition can be implemented on MATLAB/ OpenCV [25]. In ALPR recognition phase is mostly mentioned as OCR [22] [34]. Many authors have preferred to use AI based Recognition algorithm like Kohonen Self Organising (SO) model [3][4][9] [10] [21]. Line and feature detection for OCR is studied in [21]. Hausdroff distance method [39], Support Vector Machine (SVM0 [12] [50], Fuzzy rule based system [31] and statistical feature extraction is used in [30].

III. COMPARATIVE ANALYSIS OF RESULTS

Table 3.1 shows the comparison on the basis of essential parameters and results obtained by previous authors.

Table 3.1: Comparison of various techniques in terms of parameters and results

Ref. No.	Input Type	Images Studied	Key Features in Research Work	Plate Recognition Efficiency (%)	Miscellaneous Parameters
[1]	Video	100	• Line Interpretation • Euclidean Distance	95.41	Varying environment conditions
[2]	Image	100	• BPNN • Combined feature extraction	95	Adaptable to illumination
[4]	Image	5	• Hough Line Transformation • Canny Edge Detection	80	Static Input Images
[5]	Image	1729	• Dep Learning • CNN	89.33	Able to deal with distorted LP
[6]	Image	1500	• Super-resolution • Generative Adversial Network	86.45	Reduced false detection
[10]	Image	10000	• Deep Learning • Hidden Markov Model	80	Annotation free system
[11]	Image	1829	• CNN • Supervised Learning	87	Minimal Pre-processing
[12]	Image	26416	• SVM • ANN	94.43	-
[14]	Image	1000	• Multiwavelet Transform • Skew correction	98.3	Multinational ALPR
[16]	Image	100	• Raspberry Pi • Template Matching	96	-
[19]	Image	500	• Edge Histogram • K-means clustering	84.8	Real time system
[20]	Image	65	• Corner Detection • Aspect Ratio	93.84	-
[23]	Video	-	• Illumination Compensation • D-Isomap	91	-
[28]	Video/ Image	-	• Contour Enhancement • Neural Network	98.29	Multicountry system
[29]	Image	259	• Canny Edge Detection • ANN	95.36	-
[30]	Image	-	• Image Scissoring • Template Matching	82	Work in ill illumination
[31]	Image	300	• Fuzzy based Algorithm • Template Matching	90.4	Real time system
[32]	Image	-	• Mahalanobis Classifier • Region based Detection	97.6	-
[33]	Image	1287	• OCR • Probabilistic Neural Network	89.1	-
[34]	Image	1065	• Color Edge Detection • Fuzzy maps	93.7	-

I. CONCLUSION AND FUTURE SCOPE

This paper summarizes different techniques used for effective implementation of ALPR system under a variety of working conditions. The output of any ALPR system vary along with some significant extraneous factors like linear or angular way of capturing image, image/video quality, no. Of License Plates per image and environmental issues like illumination, occlusion, degraded License Plates, background noise embedded in Plate Features. All these factor may lead to false detection or incorrect extraction. Each and every algorithm and process has its own pros and cons & are better in some specific context. Some robust ALPR systems are also developed which work in unconstrained environment & recognize LP for Multinational format.

Despite of the significant amount of work done in alpr development there is still some challenges to be addressed in future like extraction of license number from a low quality image/video, to correctly recognize from blurred/ noisy inputs, to frame a universal alpr system that can detect and recognize plate styles for any country and to connect the real-time tracking and detection with database for better transportation and surveillance system.

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