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VEHICLE LICENSE PLATE DETECTION: A SURVEY

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Abstract

Automatic Number Plate Recognition (ANPR) is an image processing technique that is used to extract the symbols (characters and digits) embedded on the number (license) plate to identify the vehicles. Huge numbers of ANPR techniques have been proposed by various researchers in the past. Most of the ANPR techniques are designed for restricted conditions due to the diversity of the license plate styles, environmental conditions etc. Not every technique is suited for all kinds of conditions. In general, the ANPR technique comprises of the following three stages; license plate detection (LPD); character segmentation; and character recognition. There exist a wide variety of techniques for carrying out each of the steps of the ANPR. Some score over others. This paper presents a State-of-the-Art survey of the various leading LPD techniques that exist today and an attempt has been made to summarize these techniques based on pros and cons and their limitations. Each technique is classified based on the features used at each stage of LPD. This survey shall help provide future direction towards the development of efficient and accurate techniques for ANPR. It shall also assist in identifying and shortlisting the methodologies that are best suited for the particular problem domain.

Keywords : Automatic number plate recognition (ANPR), license plate detection (LPD), Edge detection, Texture detection.

I. Introduction

Image processing techniques find applications in a wide range of areas such as face recognition, remote sensing, medical image scanning, defense operations etc. Automatic Number plate recognition (ANPR) is one of the major areas where image processing techniques play an important role. ANPR systems are widely used in many different applications like toll management, traffic surveillance, parking management etc. The traffic surveillance system in [XXXVIII] and [XXXV] uses the license plate of the vehicles to spot the rule violators. The number of ANPR techniques that exist today is primarily designed for very specific scenarios due to the diversity of different number plate styles, different camera resolutions, different image quality and different environmental conditions. These varying constraints cater to the requirements of a specific geographical area of application.

The license plate detection phase of ANPR uses various features such as edge information, texture structure, color combination, intensity variation etc. to segregate the license plate from the captured image of the vehicles. The license plate so

obtained is used for character segmentation in the second phase, resulting in a series of segmented characters. The final phase recognizes these segmented characters to identify the vehicle number plate. A detailed discussion is carried out in this paper.

II. License Plate Detection

License plate detection is the most important task in the ANPR. The accuracy of the ANPR directly depends on the license plate detection. The license plates have diversity in different countries. The task becomes more challenging due to variation in environmental conditions, image resolution, different viewpoints of the cameras, different orientations. Many researchers have proposed various solutions to License plate detection for different nations and different viewpoints.

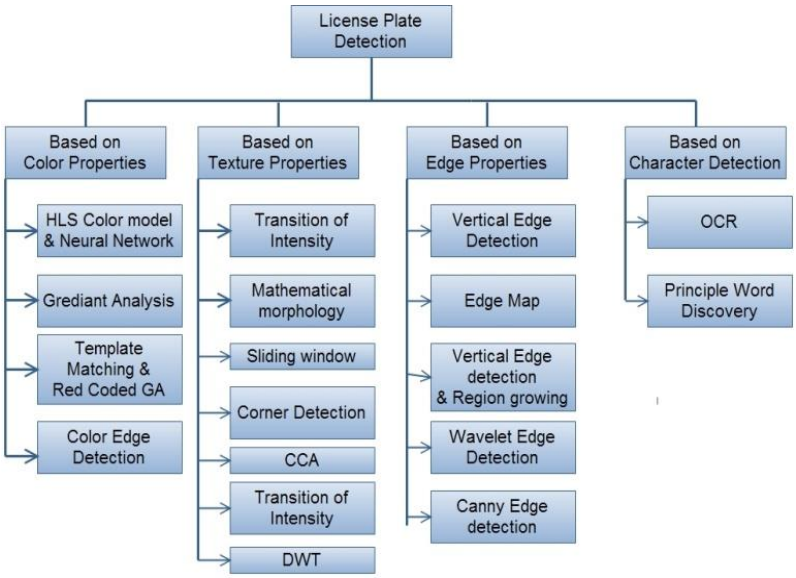

Fig.1. Classification of license plate detection techniques

In general, all the existing approaches use global features like the color combination of license plates, edge information, textures information, etc. to detect the license plate. These approaches achieve remarkable accuracy but there exist some limitations in each and every approach. This section proposes a detailed survey on all the existing methods for license plate detection and their limitations. In general, license plate detection techniques can be classified into four major categories based on the features used in these techniques. Fig. 1 shows the classification of the license plate detection techniques. The classification of these techniques is as follows:

- Based on color properties of the license plates
- Based on texture properties of license plates
- Based on the edge properties of license plates
- Based on character detection

A. License plate detection based on color properties of license plates

Every country has its own styles for license plates of the vehicles. These license plates are composed of some color combinations such as yellow background and

black characters, green background and white characters. These color combinations represent the unique property of the license plate. There exist various techniques for license plate detection using the color properties of the license plate.

1) HLS Color model and neural network

Lee et al. [XIII] proposed a method for license plate detection applicable for Korean vehicles based on the color specification. HLS color model and neural network are used to identify the license plate region. To establish the neural network, twenty-four internal nodes with eight color combination classes for input layers and four classes for output layers are designed. A standard backpropagation algorithm is used to train the neural network. The approach is tested on 80 core images of which 73 are identified correctly with 91.25% average accuracy. The major limitation of the approach is that only eight color combinations for input layers are used to identify the license plates but due to variation in illumination conditions, eight input classes are not enough to detect all possible color combinations.

2) Gradient Analysis

Comelli et al. [XXXIX] proposed a method for license plate detection specific to Italian vehicles. Italian number plates are composed of black color characters on a white background or vice versa which leads to the high local contrast in the license plate region. The gradient analysis [XXXIV] is used to detect the high local contrast features. The rectangular region having local contrast is identified as a possible license plate region. The approach is tested on 12217 images of the vehicles that are captured from the rear side. The overall accuracy achieved by the approach is 98.7%. The gradient analysis is used to identify the local contrast but due to the variation in the distance of the vehicle from the camera, gradient analysis is not enough to detect the local contrast presents in the license plate area [XXV].

Jia et al. [LIII] use the color region segmentation technique for license plate detection. The approach is developed for Australian vehicles. In the approach, mean shift [IX] and Mahalanobis [56] classification for spatial and range domain [XLIII] are used for license plate detection and verification. Different color regions are segmented based on mean shift computation in the spatial and range domain. The regions having a mean shift value greater than the threshold are discarded. A possible license plate area is isolated based on the geometric property of the license plate. The approach is tested on 87 images and achieves 98.7% accuracy. The approach faces some issues on the selection of the threshold value. In mean shift computation for spatial and range domain, a threshold needs to change concerning the resolution of the input images.

3) Template Matching and Red-Coded GA

Yohimori et al. [XLVIII] proposed a method for license plate detection based on the color combination of the license plates and template matching. The red-coded genetic algorithm [LXI] is used for threshold computation. The HSV color model and fuzzy rule sets are used to detect the possible license plate region. A template matching operation is used for the verification of the license plate region. The accuracy achieved by the approach is 95%. Wang et al. [I] use the color recognition approach for license plate detection. In the approach, edge detection is used for the detection of

the possible license plate region followed by color recognition. Fuzzy sets of Hue, saturation and variance components are designed for all possible color combinations of license plates. To identify the license plate region, all license plate regions are divided into sub-regions based on H, S, and V values. These sub-regions are classified into different ranks by using fuzzy maps and each rank represents the different license plate style. Based on the rank, a valid license plate region is isolated from the image. The approach is tested on vehicles from shanghais, Shenzhen, Beijing. The overall accuracy achieved by the approach is 93.48%. The approach gives false-positive results in case of any brand name presents on the vehicle body.

4) Color Edge Detection

Cheng et al. [XLVIII] propose a method for license plate detection for Taiwan vehicles. In Taiwan, five types of license plates with five different color combinations are used. In the approach, fuzzy member functions of different colors are defined and edge detection is used to generate the edge maps of R, G and B values of the edges. These edge maps are then transformed into HSI color model. Fuzzy member functions are based on Hue, saturation and illumination components. Based on the fuzzy aggregation of edge maps and fuzzy member functions, a possible license plate area is extracted from the image. Overall accuracy achieved by the approach is 97.9%. The approach is based on color edge detection and fuzzy member functions that require complex computations.

B. License plate detection based on texture properties of license plate

In general, License plates contain some texture on a specific background that leads to the intensity variation in the license plate area.

1) The transition of Intensity and Mathematical morphology

Soh et al. [LVI] use intensity variation to detect the license plate. To detect intensity variation, sampling of the rows at some interval is used to scan the variation in intensity. The sampled row that contains intensity variations greater than a predefined threshold value is selected as a part of a possible license plate region. Overall accuracy achieved by the approach is 99.2%. Martin et al. [XIV] propose an approach for license plate detection by using morphological operations. The approach is based on the observation that the characters on license plates have low intensity than the background or vice versa. To detect the texture feature, the Black-top Hat morphological operation [XL] is used. To obtain the black-top image a closing opposition is performed between the original image and the structuring elements. The resultant black-top image is used to obtain a new copy of the input image that does not contain the texture structure on the license plate. The license plate is obtained by subtraction of the resultant image from the input image. Aspect ratio is used for verification of the license plate. The author claim that the approach achieves 100% accuracy in license plate detection but the major limitation of the approach lies in the selection of the accurate width of the horizontal structuring element.

2) Sliding Window and Corner Detection

Opulous et al. [VII] propose a novel approach for license plate detection by using a sliding window. In the approach, two windows of different sizes are used. The small size window is placed inside another window. These two sliding concentric windows (SCWs) are used to detect the intensity variation in the input image. The difference

between the mean and standard deviation of pixel intensities in both windows is used for the selection of possible license plate regions. The pixels in the inner window are considered as a part of the license plate if the mean values and standard deviation values of both windows exceed a predefined threshold. The overall accuracy of the approach is 86.0%. The approach does not report any method for computation of the threshold values and the selection of the size of both SCWs. In an image of the vehicle, the license plate region has more corner points as compared to the rest of the part. Shi and Fu [LXII] use a corner detection algorithm to identify the license plate region. In the approach, the Harris corner detection algorithm is used to detect the corners in the grey level input image. The region that has a maximum number of corner points is considered as the license plate region. SCW is used to count the number of corner points across the image. The approach is tested on 1200 images of 320x240 pixels size and the accuracy achieved by the approach is 98.42%. The accuracy of the approach depends on the size of SCW and the threshold value for corner count. The number of corner points depends on the resolution of the image. A similar approach for license plate detection is also used in [IX].

3) CCA and DWT

Caner et al. [XVIII] propose a technique based on Gabor filter and Connected Component Analysis (CCA) [58] for license plate detection. The Gabor filter with morphological dilation operation is used to remove the noise and improve texture structure. Connected component labeling (CCL) is used to extract the connected regions from the binary image. In CCL, a unique identity (ID) is generated for the pixels that belong to the same connected region in the neighborhood. A raster scan from top to bottom and left to right is applied to perform the CCL and the largest connected region with a unique ID is identified as the license plate region. In the approach, the threshold value is needed to be changed for every new image with different illumination conditions. In the frequency domain, discrete wavelet transformation (DWT) is also used for the detection of texture features in any image.

Wang et al. [LX] use 1-level DWT to detect and extract the license plate. First level DWT followed by the noise elimination in H2 sub-band is used. In the H2 sub-band, the heights of the vertical lines greater than the threshold are removed. The variations in H2 sub-band represent the license plate region. The approach achieves 97.33% accuracy in testing on 300 different images of 400x300 pixel size with 0.18ms average execution time per image. The approach is based on assumption that the size of the license plate is always one-fifth of the width of the image but in most of the cases, size of the license plate in an image depends on the distance of the vehicle from the camera. Many approaches use binary images for license plate detection.

Wen et al. [LVIII] propose an effective method for binarization of license plate images. In a binary image, CCA is used for license plate detection. The authors propose an improved Bernsen algorithm for binarization. In improved Bernsen, Gaussian filter [LX] with adjustment parameter is used additionally with Bernsen algorithm. In the approach, the distance between two characters in a Japanese license plate is used as a benchmark for threshold computation. The approach is tested on seven different sets of Japanese license plates. The average accuracy is achieved by the approach is 97.16%.

C. License plate detection based on the edge properties of license plates

In an image, the license plate region contains a wide number of edges due to the presence of characters. This edge information may be used to detect the license plate area.

1) Edge detection and Edge map

Zhery et al. [XI] propose a method based on vertical edge detection. A Sobel operator is used to detect the vertical edges followed by noise removal using an algorithm. In the approach, edges are filtered based on the heights of edges to detect the possible license plate regions. Two threshold values are used to filter the edges, one threshold is for a maximum height of the edges and another is for a minimum height of the edges. The edges between these thresholds are considered part of the license plate region. The approach is tested on the various images of 384x288 pixels size and the accuracy achieved by the approach is 100%. The approach is based on the hypothesis that the distance between the camera and the vehicle is always the same that limit the approach to a specific scope. The authors acknowledge that the time complexity of the approach is not efficient. Guo et al. [XXV] propose another approach based on edge detection. Histogram equalization is used to improve the resolution of the image and later edge detection is performed to obtain the edge map. In preprocessing, a gradient averaging method is used to remove the non-license plate regions from the edge map. Verification of the possible license plate region is carried out using geometric properties i.e. aspect ratio, height and width. The approach is tested on 32 image capture at different illumination such as morning, afternoon, evening, night and the average accuracy achieved by the approach is 97.19%.

Jiao et al. [XXIV] propose an approach for multi-type license plates detection. The approach proposed for detection of the five different types of license plates by configuring some parameters. The values of these parameters are obtained from experiments on various numbers of license plates of different styles. First to detect the possible license region a vertical edge detection using Sobel edge detection is performed and to extracts the skeleton of a license plate a region growing algorithm is used. The approach is tested on images of the vehicles from five different nations and the overall success rate of the approach is 90.10%. The approach moves one step forward towards the generalization of license plate detection. The approach is tested on fixed viewpoint images and empirically selected thresholds are used.

Luo et al. [XXXI] propose another approach for license plate detection. In the approach, edge detection and color features of the license plates are used. In the approach, a vertical Sobel operator is used to obtain the binary edge map followed by the classification of the edge maps into yellow plates and nonyellow plates in HSV color space. The approach is tested on 2943 images of yellow and nonyellow plates. The approach achieves 95% accuracy for the yellow license plate and 98% for the nonyellow license plate. Rabee and Barhumi [IV] propose an approach for license plate detection for UAE license plates. The approach is based on vertical and horizontal edge detection. Singh [XXXVIII] also uses the Sobel edge detection technique for license plate detection. The approach is designed for Indian vehicles.

Zheng et al. [XXXIII] propose a method to improve the accuracy of edge-based license plate detection approaches using cascade classifiers [XLVI] and ada boost

algorithm [XXX]. To train the classifiers, two global features like edge density and edge density variation with four local haar-like features like pixel value, vertical edge strength etc. are used. To improve the accuracy of the approach, the classifier is also trained for nonlicensed plate regions. The approach requires complex computations for different features detection also additional training set needs to be developed for different environmental conditions.

2) Wavelet edge detection and Canny edge detection

Wang et al. [XXXVII] use edge statics for the detection of license plates. In the frequency domain, the high-frequency component represents the license plate region. Wavelet edge detection is used for the detection of high-frequency components and to improve the shape of the characters. After edge detection, the morphology operation is applied to improve the shape of the characters in license plate morphology operations are performed. Rasheed et al. [XLVL] proposed another method for license plate detection based on the canny edge detection algorithm and hough line detection. In the approach, the edge map of the image is obtained by using canny edge detection. A Hough line detection algorithm is used for the detection of the horizontal and vertical edges from the edge map. The approach is tested on 102 images out of which 96 images are correctly identified. The approach does not report any method for validation of the license plate region. An attempt has been made to generalize the license plate detection in [XVII]. Hsu et al. [XVII] propose an approach for three types of applications such as access control system, law enforcement system and road petrol. The approach may be used in all three but require some parameters i.e. pan, tilt, size of the license plate, average illumination intensity, distance of the vehicle from camera and projection orientation to be configured. In the approach, vertical edge detection and edge clustering are used to detect the possible license plate region. The accuracy of the approach depends on the configuration of the parameters according to the application. The variance in values of these parameters may lead to performance degradation.

3) OCR and Principle Word Discovery

Depriya et al. [LII] propose another approach for license plate detection. The approach is designed for Indian vehicles and the average accuracy achieved by the approach is 98%. Apart from the conventional methods, Zhaou et al. [LIV] proposed an approach for license plate detection based on principle word discovery. In the approach, to detect the possible license plate, the detection of principle words in the image is carried out. In the approach to detect the principle words, a scale-invariant features transformation (SIFT) [XXX] algorithm and template matching are used. A license plate is detection is carried out based on the word count. The average accuracy achieved by the approach is 93.2% with a 1% false-positive rate. The approach is based on word discovery that may increase the rate of false-positive detection due to the presence of presence any irrelevant words i.e. brand name, slogan etc. on the vehicle body. Table I summarized the above discussion in terms of the pros and cons of the classified techniques of license plate detection.

Table I. Comparison of different license plate detection techniques

S.No	Approach	Pros	Cons
1	Based on Color Properties	Able to detect inclined license plate	Specific to the color of license plate
2	Based on Texture properties	Simple and robust to color transition	Error-prone to noisy and blurring images
3	Based on Edge detection	The simple and fast and good accuracy rate	high false-positive rate

III. Conclusion

Huge numbers of LPD techniques have been proposed by various researchers in the past. A young researcher attempting to undertake or solve a problem using LPD techniques is bogged down by a plethora of proposals that exist today. Not every technique is suited for all kinds of problems. Some score over others. This paper presents a comprehensive survey on existing LPD techniques by categorizing them according to the features used in each stage. Comparisons of these techniques, pros, cons, accuracy, and limitations of each technique are discussed in this survey. A future forecast for LPD is also given at the end. Based on the pros and cons of various leading existing proposals, it is found that the future research of ANPR should concentrate on multi-style plate recognition, video-based ANPR using temporal information, multi-plates processing, high definition plate image processing, ambiguous-character recognition, and so on. It is noticed that in license plate detection, the technique based on texture properties of license plates achieves good efficiency in night time if used with infrared lights. In the case of average illumination conditions, the vertical and horizontal edge detection technique achieves good accuracy and low false positive detection as compared to techniques that are based on the color properties of license plates.

Conflict of Interest:

There was no relevant conflict of interest regarding this paper.

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