Improving License Plate Recognition Rate using Hybrid Algorithms

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Abstract: Vehicle license plate is the only trustworthy identity of a vehicle in Intelligent Transportation System (ITS), and corrects vehicle identification mainly depends on accurate Automatic License Plate Recognition (ALPR) system. The aim of this paper is to design a robust ALPR system that can deal with different license plate formats with different character fonts. This paper highlights a hybrid license plate extraction algorithm, Connected Component Analysis (CCA) and spectral analysis based character segmentation, finally, Linear Discriminant Analysis (LDA) based character recognition with two separate alphanumeric recognition engines.

***Index Terms* - Optical flow, edge analysis, spectral analysis, CCA, LDA**

I. INTRODUCTION

Automatic License Plate Recognition (ALPR) System is capable of reading vehicle number plates without human intervention. Accurate detection and recognition of vehicle license plate involves a wide variety of applications such as traffic surveillance and law enforcement, vehicle tracking, access control, vehicle parking automation, electronic toll collection, etc. The complexity of ALPR system lies in recognizing vehicle number plates that are not of standard form. Due to this complexity several research on ALPR system is still in progress in order to detect and recognize vehicle number plates with different formats in various environmental conditions.

A typical ALPR system involves three major phases: License Plate Detection and Extraction followed by Image Acquisition, Character Segmentation and Character Recognition. There are several algorithms proposed for each of the three phases. License plate detection and extraction [1-4] can be achieved by using boundary or edge features, global image features, colour features, character features, two or more features combined together and so on. The input to this phase is a vehicle image and the output is a portion of the image containing license plate. The above mentioned license plate detection methods involve low computational complexity and less memory but fails in case of complex scenes containing towing accessories of vehicles, large headlights, meshes, and other objects. Character segmentation is the second phase in an ALPR system whose purpose is to segment printed characters in the isolated license plate for further recognition [5,6]. This can be achieved by using pixel connectivity, projection profiles, prior information of characters, combined features, etc. But prior to this step tilt-correction and image enhancement has to be done in order to overcome the problems of tilt and non-uniform brightness. The above mentioned character segmentation methods fails when the license plate characters are joined or broken and under noisy conditions. Finally, the segmented characters are resized to a single size and fed as input to character recognition phase whose goal is to convert these printed characters into computer readable text format [7-9]. This can be achieved by using pixel values based on template matching, using extracted features obtained by one of the method like horizontal projection and vertical projection, Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA), Histogram of Oriented Gradients (HOG), by extracting topological features etc., then based on these extracted features the segmented characters are recognized using classifiers such as ANN, or SVM, or HMM, or RBF, or combination of classifiers or using simple distance measure.

The performance and final accuracy of an ALPR system depends on all the three phases. This paper is focused in designing an ALPR system that can overcome the issues addressed above. The proposed ALPR system involves a hybrid license plate extraction algorithm that is applicable to different plate formats, CCA and Spectral analysis based character segmentation and finally, LDA feature extraction based character recognition that is applicable to different character fonts. The rest of the paper is organized in six sections. In Section II, the proposed hybrid license plate extraction algorithm is discussed briefly. A CCA and spectral analysis based character segmentation algorithm is discussed in Section III. Section IV describes LDA feature extraction based character recognition with two separate alphanumeric recognition engines. In Section V, the experimental results of the proposed ALPR system are highlighted. Finally, in Section VI, the paper is concluded with the advantages of the proposed ALPR system.

II. LICENSE PLATE EXTRACTION

The first and the most important phase in an ALPR system is license plate detection and extraction, whose goal is to localize the vehicle license plate from the captured vehicle image or video. Several algorithms are used to extract license plate region, each having different complexity and difficulty. A hybrid license plate detection algorithm is proposed to address various issues faced by the existing license plate detection algorithms. The proposed method is a combination of edge analysis, morphological operations, CCA and global image features like area, aspect ratio, row-column length, spectral analysis, and corner point detection.

A. Pre-Processing

The moving vehicle detected using optical flow method is extracted and fed as input to the hybrid license plate detection phase. Due to poor illumination conditions and due to the distance of camera from the scene, the extracted vehicle will be of low contrast and blurred. The aim of pre-processing is to improve the image quality by denoising and enhancing image contrast. Bilateral filtering is applied to the gray scale vehicle image to obtain a better quality smoothened image with less blurring effect, where a bilateral filter is a non-linear filter that reduces noise by preserving edges more effectively than median filter. Adaptive Histogram Equalization (AHE) is applied to the filtered image to enhance the contrast, where AHE performs well when compared to a simple Histogram equalizer (HE), because AHE depends on gray levels, local properties and spatial co-ordinates of pixels with high PSNR, whereas HE depends only on the gray levels of pixels with low PSNR. The vehicle image may contain other regions along with the desired license plate region. With an assumption that license plate region will be either rectangular or square shaped, the search space can be reduced by eliminating disc shaped regions by morphologically opening the AHE image using a disc shaped structuring element and subtracting the opened image from the AHE image. This step also strengthens the edges and corners of license plate region. Fig. 1 (a) shows an example of an input image with bright light condition and Fig. 1 (b) shows an example of pre-processed image with strengthened license plate area.

B. Edge analysis and Morphology

Sobel operator is applied to the binary pre-processed image to detect edges. A Sobel operator has a pair of 3x3 kernels that performs 2D-spatial gradient measurement on an image and highlights the high frequency regions that corresponds to edges. Dilation is applied to strengthen the edges extracted by Sobel operator, hole-filling is applied to fill holes in the dilated image, morphological opening is applied to remove the unwanted portions in the hole-filled image, finally, erosion is applied to detect candidate license plate regions. Fig. 1 (c) shows an example of edge analysed image and Fig. 1 (d) shows an example having ten candidate license plate regions after applying morphological operations.

C. CCA and Global Image Features

CCA scans a binarized input image and groups its pixels that are connected to each other with similar pixel intensity values into components based on four or eight pixel-connectivity. CCA and global image features like area, aspect ratio, and row-column length are used to eliminate some of the candidate license plate regions that do not qualify for license plate region, thereby reduces the complexity in detecting the license plate area from the eroded image. Fig. 1 (e) shows an example of connected component analyzed image with only two candidate license plate regions.

D. Spectral analysis

Spectral analysis is based on Fourier transform computation and is expected to have maximum value at the license plate region due to the presence of characters [2]. For further analysis, it is convenient to use Fourier spectrum (magnitude of Fourier transform) or power spectrum (square of Fourier spectrum) rather than Fourier transform as it consumes more time due to its complex nature. For an M x N image, an estimate of power spectrum called as periodogram is calculated on the intensity levels of each row to check whether a character has crossed. The periodogram estimate is given in the following equation,

$$\prod_f^N(u)=\frac{1}{N}\left|\sum_{x=0}^{N-1} f(x)e^{-j2\pi nx}\right|^2 \quad (2)$$

After periodogram estimation, a threshold of 50% of maximum periodogram is set, the rows having the periodogram value greater than the threshold are considered and the pre-processed image with those rows are detected and extracted. In some cases, the extracted pre-processed image may consist of towing accessories like vehicle logo or label, large mesh, large headlights along with the desired license plate region, in such cases, corner point detection is applied to extract the desired license plate region with an assumption that maximum number of corners exist in the license plate region due to the presence of characters. Fig. 1 (f) shows an image where two candidate license plate regions are extracted and appended to form a temporary image, Fig. 1 (g) shows an example where periodogram value is maximum at the license plate region and Fig. 1 (h) shows an example of extracted license plate region.

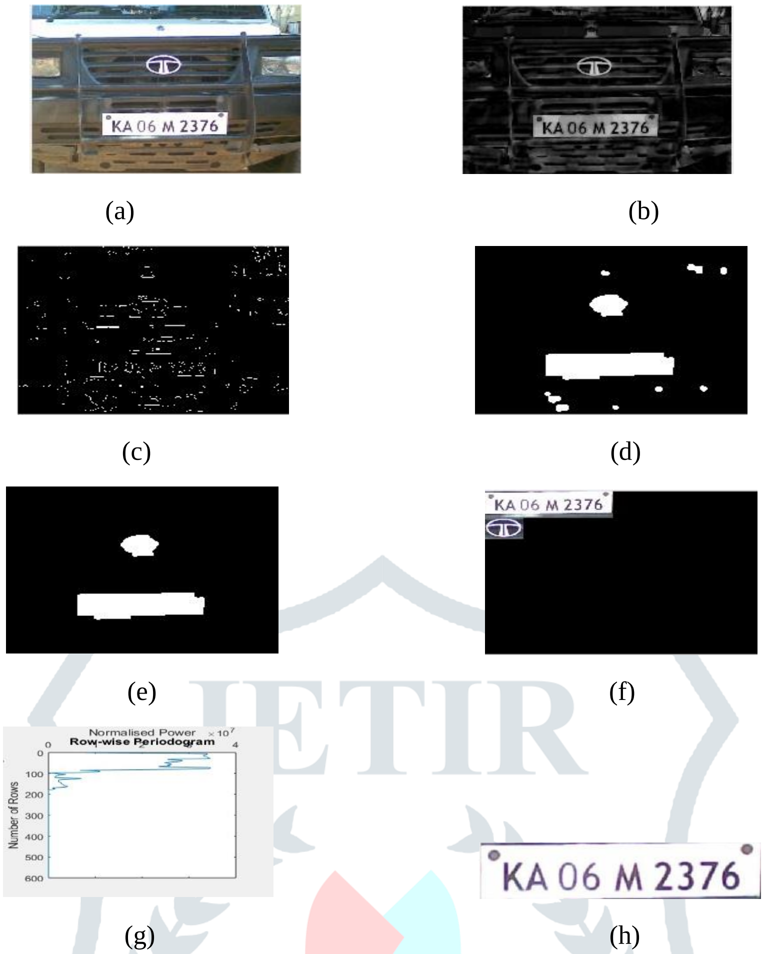


Fig. 1: (a) Input image, (b) Pre-processed image, (c) Edge analyzed image, (d) Morphologically analyzed image, (e) Connected Component Analyzed image, (f) Temporary image, (g) Periodogram plot, (h) Extracted license plate region

III. CHARACTER SEGMENTATION

Character segmentation aims at segmenting each printed character in the extracted license plate region for further recognition. A combination of CCA and spectral analysis is proposed to segment both disconnected as well as connected characters.

It is necessary to pre-process the segmented license plate as it may be rotated, noisy and blurred. The segmented license plate image is resized to 500x800 pixels, its quality is improved by applying Gaussian pyramid that removes noise and smoothens the image, image features like edges and corners are sharpened by performing unsharp masking, salt and pepper noise and Gaussian noise are filtered using median and averaging filter respectively. Eight connectivity CCA is applied on the pre-processed image and the components that do not satisfy pre-defined area, aspect ratio, row-column length, and solidity values are expected to be non-character regions and are discarded from the whole image. Row-wise periodogram is applied to find the number of lines in which the license plate characters are printed, based on the number of lines the image is divided and CCA is applied to the divided images to segment the characters. Fig. 2 shows an example of segmented license plate characters based on the proposed algorithm.

Fig. 2: (a) License plate image, (b) Segmented characters

IV. CHARACTER RECOGNITION

Character recognition is the last phase in an ALPR system that converts the printed alphanumeric characters into computer readable text format. This work proposed an algorithm where the features of alphanumeric characters of different styles are extracted using LDA and the test features are classified against the trained features using a simple Euclidean distance measure. The proposed algorithm designed two separate alphanumeric recognition engines respectively for alphabets and numbers based on some prior information about Indian license plate, and the algorithm involves a training phase and a recognition phase. Fig. 3 shows an example of LDA feature extraction and Euclidean distance measure based character recognition algorithm.

A. Linear discriminant analysis (LDA)

LDA extracts features that are capable of separating objects belonging to different number of classes and finds a linear combination of features that is further used as a linear classifier for reducing the dimensionality [8]. Compared to PCA and HOG feature extraction techniques, LDA gives good discrimination with less error rate because of increased inter-class and decreased intra-class separation.

a) Training Phase: Initially, different alphabet images of different styles are grouped into different classes. Between-class S_b and within-class S_w scatter matrices are computed using the following equations,

$$S_b = \sum_{i=1}^{C} q_i \left(\varphi_{C_i} - \bar{I}\right)^T \left(\varphi_{C_i} - \bar{I}\right) \quad (3)$$

$$S_w = \sum_{i=1}^{C} \sum_{I_k \in C_i} \left(I_k - \varphi_{C_i}\right)^T \left(I_k - \varphi_{C_i}\right) \quad (4)$$

where q_i is the number of k sample images in each class C_i, φ_{C_i} is the mean vector of all the k sample images belonging to class C_i and $\bar{I}$ is the mean of all M sample images. The Eigen vectors and the Eigen values of $S_b V = \lambda S_w V$ are computed and the Eigen vectors whose Eigen values greater than zero are selected and arranged in descending order and, the alphabet feature vector is obtained by projecting each sample image onto the obtained LDA feature space. Similarly, number feature vector is also obtained.

b) Recognition Phase: Based on the prior information about Indian license plate, the test image I_x is fed to either alphabet or number recognizer. The test feature vector is obtained by subtracting the mean image $\bar{I}$ from the test image to obtain ϕ_t which is then projected onto the LDA feature space. Finally, the trained feature vector with minimum Euclidean distance against the test feature vector is considered as the class to which the test image belongs to.

(a)

(b)

Fig. 3: (a) Segmented character images, (b) Recognized characters

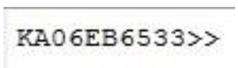
V. EXPERIMENTAL RESULTS

The performance of the proposed ALPR system is tested against different types of vehicles under different conditions. The experimental results of the proposed ALPR system using hybrid algorithms for two-wheeler, car and truck are as shown in Fig. 3, Fig. 4 and Fig. 5 respectively.

(a)

(b)

(c)



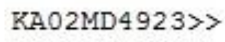
(d)

Fig. 4: Results of proposed ALPR system for a two-wheeler, (a) Two-wheeler image, (b) Segmented license plate, (c) Segmented license plate characters, (d) Recognized license plate characters

(a)

(b)

(c)

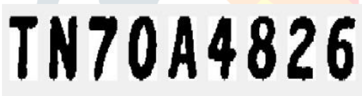


(d)

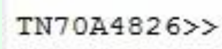
Fig. 5: Results of proposed ALPR system for a car, (a) Car image, (b) Segmented license plate, (c) Segmented license plate characters, (d) Recognized license plate characters

(a)

(b)



(c)



(d)

Fig. 6: Results of proposed ALPR system for a truck, (a) Truck image, (b) Segmented license plate, (c) Segmented license plate characters, (d) Recognized license plate characters

VI. CONCLUSION

An ALPR system is capable of recognizing vehicle license plate without human intervention. The two main industrial applications of an ALPR system are to detect traffic violations at urban intersections and counting the number of vehicles on highways. Several researches on designing a robust ALPR system is still in progress due to the complexity in recognizing vehicle number plates that are not of standard form. An ALPR system addressing this issue is proposed and developed in MATLAB R2015a version, and the stage-wise results are showed in the respective sections.

By using the hybrid algorithms for license plate extraction and character segmentation, the overall performance of an ALPR system is improved. Compared to the existing ALPR systems, the proposed ALPR system using hybrid algorithms detects and segments license plate of different shapes in both bright and dark illumination conditions, shadowed, reflective, and soiled conditions, segments characters printed in both single line and double line, segment the characters that appear to be connected due to the presence of shadow or due to the inclination of camera from vehicle, and also recognizes both standard and nonstandard license plate characters. Due to two separate alphanumeric recognition engines the recognition accuracy is improved, the recognition rate can still be improved by using SVM or RBF classifier.

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