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An efficient automated vehicle license plate recognition system under image processing

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ABSTRACT

An automated vehicle license plate recognition system using image processing techniques identifies vehicle numbers without human interference. This system has significant impact because of its good application in various fields like car parking, access control, speed control, automatic toll collection, border security, traffic violence detection and surveillance applications. This paper presents a methodology that is quite simple but at the same time very much efficient and this system consists of four sequential modules which are preprocessing, number plate extraction, number plate character segmentation and character recognition. Preprocessing aims to improve the image quality that is captured in various illumination conditions and stick out outstanding information that we need, which is favorable to subsequent processing including extraction, segmentation and recognition. After preprocessing various morphological operations are applied to extract the desired license plate region. Then for segmentation the bounding box method is applied that segments each letter and number present on the license plate region. Finally, template matching is applied in identifying all segmented characters present in the license plate image. The experimental results showed that the proposed system can recognize license plate characters efficiently with higher accuracy. Using MATLAB software, the proposed method attains recognition accuracy of 94.17%.

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1. INTRODUCTION

Nowadays vehicles are increasing exponentially because of population growth and their needs. So, the efficient and effective recognition of the vehicle license plate detection system is very important. License plate recognition system uses image processing techniques that retrieves the vehicle number from a given license plate image as a form of digital string of characters. This system is important because it plays an indispensable role in automatic inspection of effective traffic control, transportation systems and also in security systems.

Over the past few years, many techniques have been developed by researchers to detect number plates but still it remains a challenging task. Due to several factors such as poor image resolution, non-uniform illumination, reflection, varied weather, variety of fonts, camera quality affects the vehicle license plate

detection procedure. And the quality of the vehicle license plate recognition process will directly affect the speed and the accuracy of the whole vehicle license plate detection system.

Lot of researchers had experimented with different procedures to implement the vehicle license plate detection system. These approaches applied by researchers to improve the speed and accuracy of the license plate recognition system progressed day by day. Some of these approaches are reviewed below:

Selmi *et al.* [1] proposed a framework based on the mask region convolutional neural network which was applied in three stages of license plate detection, recognition and segmentation. This system was evaluated under several datasets containing images acquired from several hazardous conditions with multi-languages and multi-orientation license plates. Kessentini *et al.* [2] proposed a system architecture for the that used two deep learning stages pipeline which could be used for multilingual and multi-norm license plate identifications. This proposed system recognition accuracy was 91.46% over Radar dataset and 97.67% over GAP-LP dataset with a rational computational time.

A deep learning based vehicle license plate recognition system was introduced that incorporates optimal K-means (OKM) clustering for license plate segmentation and convolutional neural network (CNN) for license plate identification [3]. This system used Krill Herd algorithm with OKM clustering technique in segmenting license plate characters and CNN model was used in recognizing license plate characters. The test was performed on three datasets namely FZU Cars, Stanford Cars, and HumAIn 2019 challenge dataset and attained accuracy of 0.981 on the applied datasets. A single neural network for detecting and recognizing a mixed style license plate where two parallel branches of object classification and detection were presented for vehicle license plate detection and recognition [4]. This system produced the license plate type and the license plate string skipping the intermediate and some repetitive steps and classified the branch of license plate to support mixed style and multiple license plates in an integrated framework.

Chowdhury *et al.* [5] proposed a model named fractal series expansion method for the enhancement of license plate image. This model calculates the highest probability for the pixels of the license plate with the pixels of background and based on this entropy information enhancement was done. An on-line real time intelligent license plate recognition system was developed using the fusion of connected component analysis and spectral analysis at the stage of license plate extraction and segmentation [6]. A super-resolution framework for license plate images was designed which was composed of two components domain priori GAN and progressive vehicle search that exploits to integrate all the synthetic license plates into an image with highest resolution [7].

Yousif *et al.* [8] proposed a methodology that combines the genetic algorithm with an optimized neutrosophic set and image processing algorithms. The methodology proposed in this paper was used for increasing the recognition rate of license plates (Arabic-Egyptian) and English. To localize the license plate, some image processing techniques like edge detection and morphological operation were used and for extraction the genetic algorithm with a neutrosophic set was used. Farag *et al.* [9] presented a method using image processing techniques that regulates the entrance of smart parking. For larger image discrete wavelet transform was used for feature extraction at the preprocessing step that decreased the time at detection stage. At segmentation stage correlation method was used and in case of similarity support vector machine [10] was used for classification in this system.

Marzuki *et al.* [11] proposed a four-layered CNN architecture which was used for license plate detection. The learning algorithm used in training the CNN was an improved version of stochastic diagonal levenberg marquadt algorithm [12] and a smoother error gradient was achieved. Yaacob *et al.* [13] proposed an automated system that kept continuous track of entry and exit at the gate of university campus and used template matching technique at character recognition stage. The accuracy rates of this system for the plate recognition, character segmentation, and character recognition were 91.58%, 93.11% and 80.25%, respectively. A comparative analysis of vehicle accidents was done by testing a number of network topologies and also number matrices were used in the estimation process which identify the best networks [14]. The study showed that CNNs made classification and detection results more accurate and the network detectors with deep CNN topologies intensify the accuracy rate of accident classification. A multivehicle detection and vehicle license plate recognition system under complex traffic backgrounds was proposed based on a hierarchical region convolutional neural network (RCNN) by Tu and Du [15]. A multiple class classification problem was solved by this RCNN that used multiple-level networks for smaller blocks of sub tasks that enables the upgradation of network when complexity arises so that the computational load was reduced.

An automatic layout independent license plate recognition system based upon the state-of-the-art you only look once (YOLO) object detector which contains an integrated approach for license plate layout classification and detection and using post-processing rules improves the recognition results [16]-[18]. This network was trained using images from several datasets such as ChineseLP, OpenALPR-EU, and UFPR-ALPR with the addition of several data augmentation techniques as a result the system was robust under different conditions. Ahmed *et al*. [19] implemented an analysis and design of a simulation model of vehicle license

plate recognition system using image processing technology. The horizontal and vertical projections and co-occurrence matrix were applied to extract the editable text from the extracted plate's information. An algorithm was designed which integrates an adaptive image segmentation technique named as connected component analysis and sliding concentric windows with a character recognition neural network for identification of the vehicle license plate [20]. For the optical character recognition system, a two-layer probabilistic neural network was used and a trained network was used in identifying characters from the vehicle license plate image based on the data acquired from algorithmic image processing.

The proposed automatic license plate recognition system consists of four sequential modules which are: input image preprocessing, license plate region extraction, license plate character segmentation and license plate character recognition as shown in Figure 1. The system is implemented and simulated on MATLAB 2018b software.

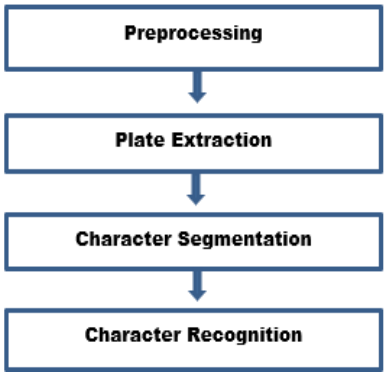

Figure 1. Major steps involved in automated license plate character recognition system

The main contribution of this paper is to provide an efficient way that recognizes license plate characters with higher accuracies than other existing systems using image processing techniques. The proposed method can accept all kinds of colored images as input and returns characters present in the license plate as a form of string more accurately than any other existing system. The rest of the paper is organized as follows. Next section briefly introduces the research methods involved in converting the input image into a form of string of characters present in the vehicle license plate image. Experimental works and results are discussed in section 3. And finally, the paper is concluded in section 4.

2. METHOD

The major steps involved in this system are divided into four major steps which are; 1) input image preprocessing, 2) license plate region extraction, 3) license plate character segmentation, and 4) license plate character recognition. In the first phase of preprocessing the input image is processed so that the image quality is enhanced and it also provides a noise free image. This step is very important for the accuracy of the license plate character recognition. At the second phase probable plate region is extracted from the larger scene using some morphological operations. And at the third phase character segmentation is done where each object is labeled using connected component analysis. Finally, each character is matched with available templates stored in the database using template matching techniques that will recognize each of the characters present in the license plate image. The overall flowchart of the processing of license plate detection system is illustrated in Figure 2.

2.1. Image preprocessing

The preprocessing stage aims at processing the input image so that the image quality is enhanced which is very much important for the next process [21]. The effects of preprocessing and result of applying the nonlinear bilateral filter on the gray scale image is shown in Figure 3. In the preprocessing step, the RGB image of the vehicle shown in Figure 3(a) is first transformed into a gray scale image as shown in Figure 3(b) according to (1). So that the resulting two-dimensional image will carry only pixel luminance values ranging from 0 to 255 where 0 indicates pure black and 255 indicates pure white.

$$I=0.299*R+0.587*G+0.114*B \quad (1)$$

The resolution of the image is reduced using MATLAB function as a result the image computing time will also decrease. Images captured in real time may consist of noises which affect the quality of the image. So, the reconstruction of the image is necessary in order to get a noise free image and without losing any piece of information from the image [22]. Bilateral filtering is applied to eliminate these noises and the result of this filtering preserves edges more effectively than median filtering shown in Figure 3(c).

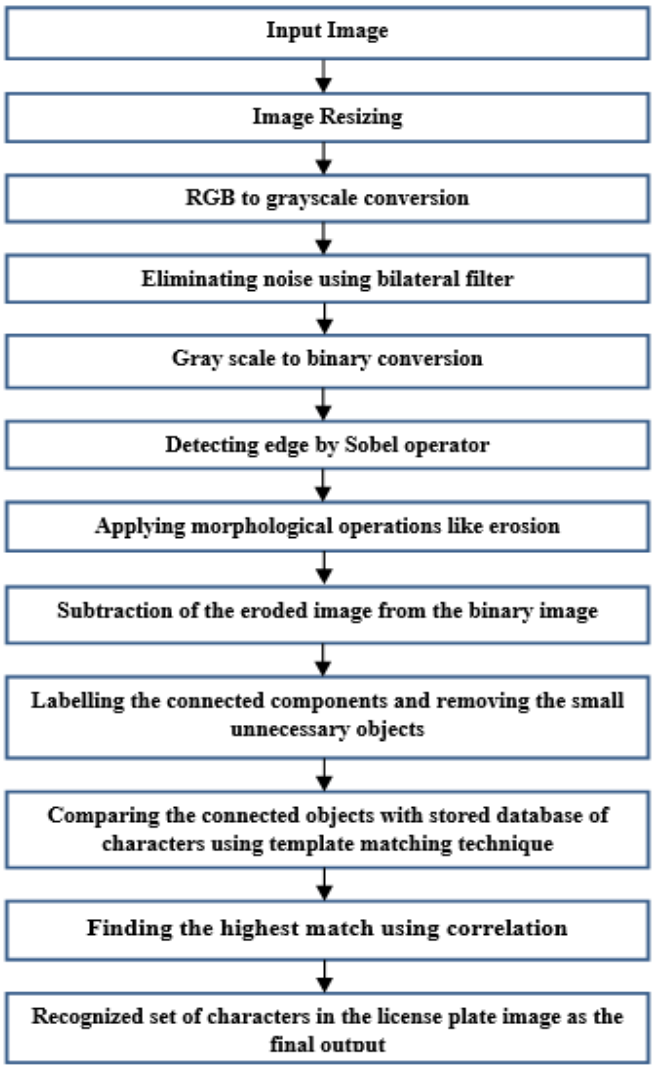

Figure 2. Flowchart of the proposed automated license plate recognition system

(a) (b) (c)

Figure 3. Effects of preprocessing (a) original image, (b) gray scale image, and (c) applying bilateral filter on gray scale image

2.2. License plate localization

After preprocessing, the next step is to extract the appropriate license plate region from the vehicle image shown in Figure 4. It is a very crucial step because the next two steps depend on the accuracy of the extraction of the plate region. Initially at this step the filtered gray scale image is converted into binary image as shown in Figure 4(a) using MATLAB function imbinarize which creates a binary image along with a global threshold. This imbinarize function uses Otsu's method [23], that replaces all values above a globally determined threshold with 1(white) and sets the rest of the values to 0(black).

Sobel filter is applied to identify the edge of the binarized image shown in Figure 4(b) when there is a sharp variation in intensity gradient of the image. The Sobel edge detection method detects edges of the image using the derivative approximation and returns edges only at those points where the gradient of the image is maximum [24]. After detecting edge, MATLAB function imfill(E,'holes') are applied to fill the holes in the input image E and morphological function bwmorph(E,'thin') is applied that performs a thinning operation. While thinning it removes pixels from image E so the image without holes compresses to a minimally connected stroke and the image with holes compresses to a ring halfway between the hole and outer boundary.

Morphological operations erosion is also used for the extraction of the vehicle license plate region from the vehicle license plate image. Morphological function imerode erodes pixels on object boundaries in the image. This erosion operation is performed using line shaped structuring elements and the result is shown in Figure 4(c). The boundary of the number plate which after detection is subtracted from the morphologically thinned image using imsubtract function to get the desired license plate region consists of the number and characters shown in Figure 4(d).

Figure 4. Steps during license plate localization (a) binarized image, (b) results of applying sobel filter, (c) results of erosion, and (d) extracted candidate region

2.3. License plate character segmentation

In the processing stage of the character segmentation process, each character is leveled individually to recognize characters from the extracted license plate region. In this process it scans through the whole binarized image and identifies each connected component in the image. After identifications of connected components, it assigns a unique level that will differentiate each object from others shown in Figure 5. In this study connected component analysis is done through bounding box approach [25]. The bounding box method creates an imaginary rectangular box over each connected component through MATLAB function regionprops as shown in Figure 5(a). It will divide the number plate into different sub images along with some unwanted objects where each sub image holds one character. And at the final steps of this stage the objects that do not have minimum height and width dimensions are deducted from the final license plate by removing small sized connected pixels shown in Figure 5(b).

(a) (b)

Figure 5. Segmentation process (a) plate region with connected components and (b) final plate region by removing small objects

2.4. License plate character recognition

At the final step, all the segmented characters are identified using template matching technique. Template matching is a digital image processing technique that compares the small components of an image which match with a template image. Using the template matching procedure, each of the segmented characters are matched with the stored alphanumeric database to find the highest match. Stored database contains 36 characters in the template form among them there are 26 letters and 10 numbers and the templates are rearranged in the order: {0,1,2,3,……..,9,A,B,C,D,…..,X,Y,Z}. Now the similarity between correlation coefficient between template image and extracted leveled image are calculated. It calculates the highest match and finally displays the recognized license plate character in an editable format of notepad as shown in Figure 6.

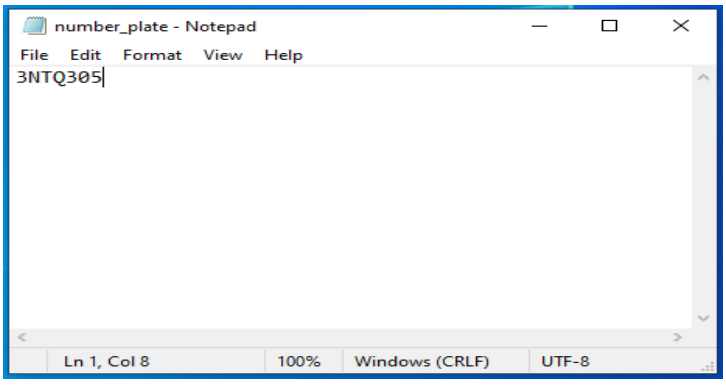

Figure 6. Recognized characters of vehicle license plate in a log file

3. RESULTS AND DISCUSSION

In this system, an efficient approach is designed to detect and recognize the vehicle license plate automatically using image processing techniques. The simulation process is carried under MATLAB 2018b software and the processor used is Intel(R) Celeron(R) 1.60 GHz CPU with 64-bit operating system. The input image is preprocessed using different image processing techniques and also in this phase noise from vehicle image is tried to eliminate using bilateral filtering. The preprocessing step has produced a good outcome which leads toward a high error free vehicle license plate recognition system. After getting the noise free grayscale image some morphological operations are applied to enhance and at the meantime license plate region is also detected using the morphological operations. In the extracted image each object is leveled using connected component analysis and bounding box method. And finally, template matching and correlation is applied in identifying each character in the license plate. A total of 120 sample license plate colored images have been tested in this experiment and this system produces an effective outcome compared to the existing system [13]. The obtained accuracy of the proposed system is 97.5%, 96.67% and 94.17% at the stage of license plate extraction, license plate segmentation and license plate character recognition respectively as shown in Table 1.

Table 1. Performance analysis of the proposed system

Phases of the proposed system	Number of accuracies	Error rate	Accuracy rate
License Plate Extraction	117/120	2.5%	97.5%
License Plate Segmentation	116/120	3.33%	96.67%
License plate character recognition	113/120	5.83%	94.17%

4. CONCLUSION

Although a good number of researches are carried out in detection and recognition of vehicle license plates, still it remains a challenging task. The proposed system is efficient and gives satisfactory results compared to other existing license plate detection systems and it also works well on low resolution, low contrast images. But some difficulties may occur while the image plate is broken or similarity between ambiguous characters like 0 and O; 1 and I; 5 and S and images with serious defects may produce wrong results. The future research could be carried out in the recognition of high-definition license plate image, multi-style license plate image and multi-plates license plate image using advanced features of artificial intelligence. The segmentation procedure can also be improved using advanced tools and techniques of image processing to reduce processing time and speed up the recognition rate.

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