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An image enhancement-based License plate detection method for Naturally Degraded Images

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Abstract

This paper proposes an image enhancement-based license plate detection algorithm to improve the overall performance of system. Non-uniform illumination conditions have huge impact on overall plate detection system accuracy. In this paper, we propose an algorithm for color image enhancement-based license plate detection for improving accuracy of images degraded by excessively strong and low sunlight. Firstly, the image is enhanced by Multi-Scale Retinex algorithm. Secondly, a plate detection method is employed to take advantage of geometric properties of connected components, which can significantly reduce the undesired plate regions. Finally, intersection over union method is applied for detecting the accurate location of number plate. Experimental results show that the proposed method significantly improves the accuracy of plate detection system.

Key words: Plate detection, image enhancement, non-uniform illumination, Multi-Scale Retinex, IoU

Ⅰ. Introduction

Due to advancements in high definition (HD) technology and its availability in mobile and digital cameras. Images and videos have become an essential part of everyday life ranging from personal use, entertainment and object detection etc. An object detection method helps in surveillance, to monitor traffic congestion, avoiding collision [1]. Real time applications of object detection such as vehicle plate detection and recognition are widely being used in Intelligent transport systems (ITS) applications such as toll payments, parking entrance and security applications, etc. All the above-mentioned applications require license plate recognition method that uses computer vision-based techniques to recognize vehicle by its number plate. License Plate Recognition (LPR) consists of 3 steps: license plate detection (LPD), character segmentation, and recognition [2]. Plate detection is the crucial step, as it has direct impact on overall accuracy of LPR system. For real-time ITS applications, LPD system should be fast enough to detect each vehicle of interest in an image or video [3]. LPD systems presented in [4] shows poor performance when system is exposed to uneven light.

Most of the developed systems show good performance in constrained environment [5]. However, for ITS applications system has to face changing illumination conditions, complex backgrounds, etc., which makes LPD a challenging task for accurate detection of plate. Other plate detection algorithms based on feature extraction [6] and neural network [7] provide good accuracies

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in controlled conditions. However, their performance is degraded when this system is tested under bad or non-uniform illumination conditions. Non-uniform conditions occurring due to exposure to excessively strong and low sunlight, are crucial factors which effect the overall detection process. Therefore, firstly, images should be enhanced to improve the quality, which helps to increase the accuracy of detection.

In the past years, many methods have been presented for color image enhancement, which can mainly be divided into two categories, histogram equalization (HE) based and retinex theory-based enhancement methods. The Image exposed to strong or low light will produce low or high dynamic range histograms.

HE focusses on stretching the concentrated values to entire range to produce uniformly distributed images having good contrast and luminance. HE remaps image grey values based on probability distribution function for input values [8]. Conventional HE methods produce undesirable effects. Dynamic histogram equalization [9] and BPDHE [10] were presented to remove artifacts but these methods lack to produce clear details for dark images.

Retinex model explains that human color perception is accomplished by both retina and Cortex. Land and McCann [11] made assumption that image is product of illumination and reflectance and by reducing the illumination effect of image can be enhanced. In [12], SSR was developed around center/surround Retinex theory but it produces compression for small scales and lightness rendition. To address this problem weighted scale, SSR was introduced known as MSR [13]. However, it produced color distorted images.

In this paper, an algorithm for license plate detection for images exposed to bad light conditions (natural images in which plate detection is difficult due to exposure to strong or low sunlight) is proposed.

PCA extracts luminance channel keeping all channels orthogonal to each other that allows stability in colors even though Luminant channel is modified. Then MSR enhances the luminance channel, followed by calculation of ratio between enhanced and original channel. This ratio is multiplied with original R, G, and B values to compute new values followed by contrast stretching of each new R, G, and B channel.

II. Image enhancement

Outdoor applications such as LPD systems are enormously affected by non-uniform illuminations occurring thought out the day. Exposure to strong sunlight will produce bright images and exposure to low sunlight will have dark images, which affects the accuracy of the detection system. Fig. 1 shows the overall system architecture of proposed system.

Therefore, image enhancement is crucial step for improving overall accuracy of any object detection system. For our proposed license plate

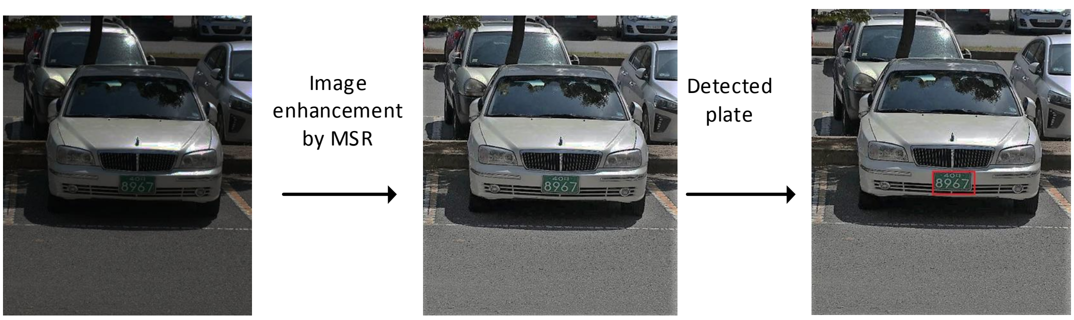


Fig. 1 overall system architecture.

detection system, image enhancement is achieved by Multi Scale Retinex (MSR) [16]. Fig. 2 describes the flow chart for image enhancement. Proposed MSR based approach consists of following steps. Firstly, Luminant and chromatic components of input image are extracted by applying Principal component analysis (PCA) [14]. Next for image enhancement, MSR method is applied only to luminance signal which contains maximum energy to obtain color constant results, where graying-out effect of an image is obtained when MSR is applied to RGB image. MSR output is integration of multiple single scale retinex (SSR) outputs, which results in better dynamic range and color constancy.

MSR method uses convolutional operation for image enhancement, which is computationally intensive and consumes a lot of time. Therefore, Discrete Fourier transform (DFT) is introduced for optimizing and speeding up the process by using multiplication in frequency domain instead of convolution in time domain. DFT can be performed using Fast Fourier Transform (FFT). As the PCA luminance signal has two dimensions, 1-D FFT is applied on each row and column separately, resulting in much reduced processing time.

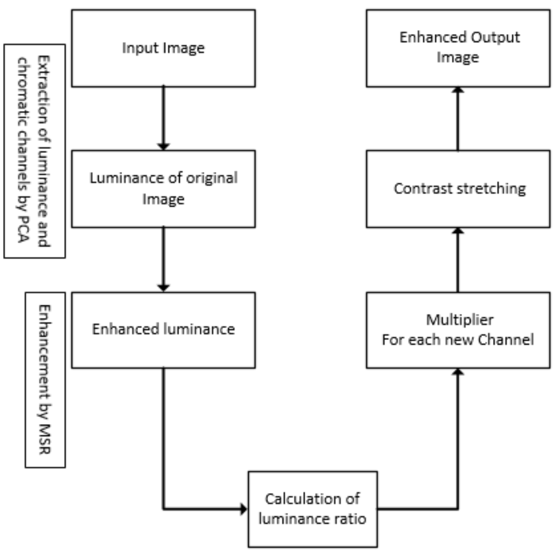


Fig. 2. Flowchart of enhancement algorithm.

Next, ratio of luminance value enhanced by MSR to original value is calculated and multiplied by each original R, G, and B channels to compute new values. At the last, contrast stretching was performed on new R, G, and B values in order to obtain the output enhanced image. Table 1 shows the algorithm for image enhancement.

Table 1. Enhancement algorithm.

$I(x, y)$ input colored image

Extraction of luminance value using PCA from each channel of colored image

For each channel

For c_i ; $i = 3$

$$SSR_i(x, y) = \log I_i(x, y) - \log[F(x, y) * I_i(x, y)]$$

End

$$\text{MSR }(x, y) = \sum_{n=1}^{3} w_n \{\log I(x, y) - \log[F^{-1}(I'(u, v)F'(u, v))]\}$$

Where I' and F' DFT and $w_n = {}^{1}/_{3}$

Luminance ratio = ${}^{Enhanced\ luminance}/_{luminance}$

$$\text{New R,G, and B values} = \begin{Bmatrix} Ratio \times original\ R\ channel \\ Ratio \times original\ G\ channel \\ Ratio \times original\ B\ channel \end{Bmatrix}$$

Contrast stretching on each channel

$$\text{New Pixel} = \frac{old\ pixel\ value - Low\ pixel\ value}{High\ pixel\ value - Low\ pixel\ value} \times 255 \begin{Bmatrix} Low\ value = 5 \le low\ pixel\ value \le 26 \\ High\ value = 255 - low\ pixel\ value \end{Bmatrix}$$

End

Ⅲ. Plate Detection

After the image has been enhanced, proposed algorithm proceeds to plate detection step. Fig. 3 shows the flow chart for plate detection. Firstly, the enhanced image is binarized using Otsu’s threshold method. Binarization helps in reducing invalid information and highlights the area of interest in the image.

After binarization, image contains groups of connected pixels. Connected components labelling is used to label group of pixels. Proposed method uses ‘8-connectivity’ method for labelling. Every connected component has different label and each pixel in the connected component has same label. Now labelled image has candidates for plate which are minimized by applying geometric properties like area and aspect ratio. Pixels area and aspect ratio vary with respect to distance from vehicle. Therefore, after performing number of experiments, area was set to be between "5000-10000 pixels" and aspect ratio to be "0.2-0.4".

Final step is to assign score to remaining connected components by intersection over union (IoU) method. Bound boxes are drawn over connected groups of pixels. Connected pixels are termed as C and corresponding Bound boxes as B. Each bound box is assigned a score t, $0 \leq t \leq 1$. For the rectangular shape of license plate, this method first detects all rectangular shapes in the image. Then, the LP is found by calculating a similarity score between bound box drawn and its corresponding group of connected pixels.

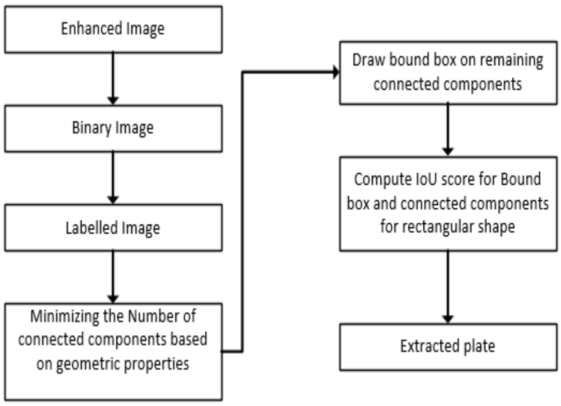


Fig. 3. Flowchart of plate detection method.

For each group of pixels, we get a score t ranging from *0* to 1, which is calculated as

$$t = \frac{area(C \cap B)}{area(C \cap B)}$$

Bound box with highest score is considered to be the number plate.

IV. Results

Proposed system is evaluated in this section and compared with conventional approaches when applied for plate detection applications. For our experiments, we have collected 1,000 vehicle images under varying light conditions. 785 images were captured using vehicle personal recorders equipped in the car and the others were used from PKU [16] data set.

Table 2 compares the performance of proposed method with existing approaches as well as testing parameters like PSNR, which is used to measure ratio between maximum possible power of signal to power of noise effecting the quality of its representation and is defined in equation (1)

$$\text{PSNR} = 10 \log_{10} \frac{255 \times 255}{MSE} \tag{1}$$

And mean square error (MSE) is defined in (2).

$$\frac{1}{MN} \Sigma_{i=0}^{M-1} \Sigma_{j=0}^{N-1} (|Y(i,j) - X|(i,j)|^2) \tag{2}$$

Experimental results show the superiority of proposed enhancement technique in terms of PSNR, execution time and plate detection accuracy.

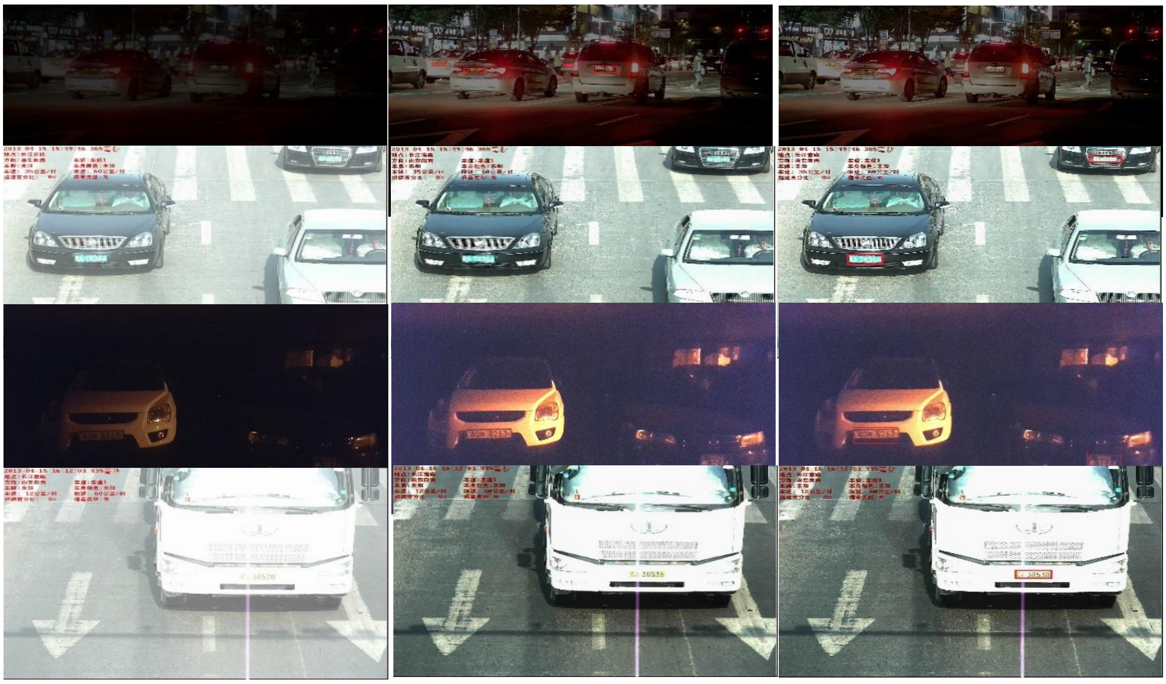
Table 2. Comparison with conventional Methods.

Method Parameter	SSR	MSRCR	NTF	Proposed
PSNR(dB)	21.573	20.875	22.973	34.698
Time(s)	1.102	1.987	2.457	.036
Accuracy (%)	87.53	89.97	93.14	96.89

It can be seen clearly that the accuracy of proposed enhanced image-based plate detection method is far better than existing approaches and is also more robust to illumination conditions. Proposed method has outperformed SSR-based method [18] by "9.36%", MSRCR [18] by "6.92%" and NTF-based method [17] by "3.75%".

Proposed method is computationally faster than existing methods. Moreover, it is suitable for real time applications due to simple architecture and less execution time. Fig. 4 shows the superior performance of proposed algorithm on images under diverse conditions. Left image shows a degraded image by the strong and low light. These images have color distortion and details are also not clear, due to cameras having less dynamic range and poor color constancy.

Enhanced images shown in the center have good color interpretation and improved appearance



(a) (b) (c)

Fig. 4. Outputs of Plate detection system (a) Original Images (b) Enhanced images (c) Detected plate.

has much clearer details of the information i.e. license plate.

Images on the right show plate detection results. We observe that proposed detection algorithm has shown excellent results on enhanced images and was successful to detect plates in varying light conditions, orientations, sizes, etc. Moreover, proposed system performed well for low resolution images, where other conventional approaches failed to perform well. Similarly, Table 3 describes the effect of proposed method on images exposed to strong sunlight and low sunlight. Our method results are better than existing methods. However, it produced better results for images exposed to strong sunlight in comparison to low light conditions.

Table. 3 Detection Accuracy

Method Environ.	Orig.	SSR	MSRCR	NTF	Prop.
E Brig. I.	80.13	89.36	91.43	94.54	97.93
E Dark I.	73.01	85.69	88.51	91.73	95.85

Environ. Stands for Environment
E Brig. I. stands for Excessive Bright image
E Dark I. stands for Excessive Dark Image

V. CONCLUSION

In this paper, we developed an algorithm to improve plate detection accuracy by enhancing the degraded images by exposure to excessively strong and low sunlight. Images are enhanced using multiscale retinex algorithm followed by plate detection. Experimental results showed that proposed method outperformed conventional methods by achieving accuracy of 96.89% and execution time of 36ms. Existing methods are not suitable for real-time applications due to complexity, which is resulting in high execution time. But, proposed methods can achieve fast execution time and make it appropriate for real-time applications. Future work will include hardware implementation of this algorithm.

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