Edge Assisted Fast Binarization Scheme for Improved Vehicle License Plate Recognition

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***Abstract*—Identity of a motor vehicle is usually through its license plate. Automatic vehicle license plate recognition has several applications in intelligent traffic management systems. In this paper, we propose and describe a fast edge assisted adaptive binarization technique for improved extraction of text from license plate images captured using mobile phone camera. We evaluate and compare the performance of the proposed binarization scheme with some well known algorithms on real vehicle images. Experiments on 400 real vehicle images captured using mobile phones shows that the edge based scheme is not only fast but also performs as well as the other binarization technique.**

I. Introduction

License Plate Recognition (LPR) systems are usually designed to automatically read the license plate of vehicles passing through a certain region and at a certain distance from fixed cameras. Although systems exist for mass surveillance that utilizes optical character recognition (OCR) and hardware capable of reading license plates of moving vehicles [1], [2], [3], there is continued interest [4], [5], [6]. In all the existing systems the camera is fixed and is therefore only able to scan the vehicle passing through a particular region in space. On the other hand, a mobile LPR system is a helpful tool in the hands of police to get details of the vehicle when required on the road 24×7. A mobile phone camera based LPR [7] system has two parts (a) mobile client which enables capture of the license plate images of a vehicle and send the image to a remote server for recognition and (b) a remote server where the recognition of the number plate happens; additionally the server has access to an external database which has vehicle number and vehicle information association details.

In this paper we address the problem of image binarization and text region extraction from vehicle license plate images captured using mobile phone cameras. The process of binarization plays a major role in effectively localizing the text region in the license plate and further greatly assists in the character extraction and recognition tasks. Several binarization techniques[8] have been cited in the literature but none of them are specially designed to preserve the text region in the image. Further low quality images due to severe illumination conditions, vehicle motion, viewpoint and distance changes, complex background cause additional challenges in the binarization process for a mobile vehicle license plate recognition (LPR) system.

The LPR system resides on a server and is a hub of several image processing and pattern recognition modules [7]. The important functional units include image pre-processing, binarization, heuristic filtering and character recognition. After color to gray image conversion the next task is to binarize the image so as to preserve the text region of the license plate so that no text region of interest is lost; the application of heuristic filtering eliminates any not-text components that would have passed through the binarization process.

It should be noted that there is no known standard test bed, to the best of our knowledge, to test the performance of a LPR system; hence we collected our own data. Additionally, we needed to work on mobile camera resolution images with the understanding that these images had to be transferred to the server for the purpose of recognition. With this in mind, we collected vehicle images as follows: (a) the images used for the study are color images of actual Indian license plates taken under various conditions (b) all images are of size 640×480 taken with different mobile phones at our disposal. The database contained a total of 400 images of 129 different vehicles. Our collection of images had a fair deal of variability in terms of lighting conditions, shadows on the plate region, plates from front or rear part of the vehicle with messages or icons, skewed images and background and foreground of the number plate. The main focus of the paper is to propose a binarization technique that preserves the text region and enables extraction of characters from the binary image. The paper is organized as follows: in Section II we describe the role of binarization in text region extraction with the help of most used Otsu's thresholding technique and propose a fast edge based thresholding technique for effective text region extraction, this is one of the contribution of the paper. The performance of the proposed algorithms are analyzed and compared in Section III and conclusions are drawn in Section IV.

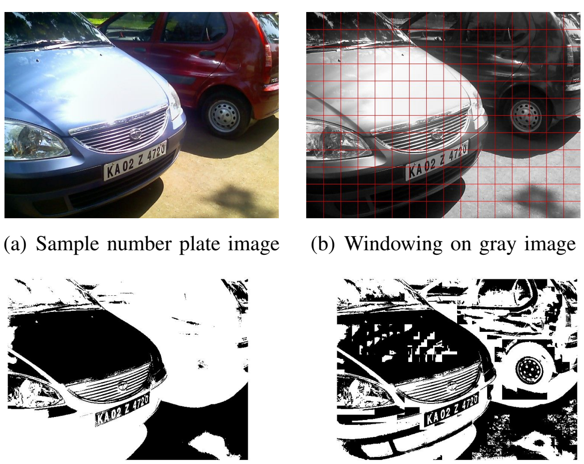
II. Binarization for text region extraction

Separating the foreground and the background in an image is an important pre-processing step in image analysis, its purpose is to acquire some useful information in the image for processing. Binarization is a widely-used technique and generally, its process is to first determine a gray threshold (G_T) according to some objective criteria and then assigns each pixel (I_{xy}) to one class (such as the foreground) if $I_{xy} > G_T$

and if $I_{xy} \leq G_T$ to the other class (such as the background). There are several G_T determining techniques for binarization reported in literature. Binarization process is broadly classified as global or local [9], [10], [11], [12] based on how the threshold is calculated. In [8], the authors describe and evaluate the performance of about 40 different G_T determining algorithms. The 40 thresholding methods are categorized into the six classes: histogram shape-based methods, clustering-based methods, entropy-based methods, object attribute-based methods, the spatial methods and local methods based on the local characteristics of each pixel. Among these classes, many thresholding algorithms are based on independently defined criteria to acquire the optimal segmenting threshold, for example, the famous Otsu's method is a thresholding technique based on a linear discriminant criterion [13] and the more recent Kwon's threshold selection method [14] is based on a clustering criterion. In this paper we propose a new edge based adaptive thresholding method which is capable of preserving the text region of an image robustly in real life conditions. We compare the proposed binarization scheme with the well known Otsu's binarization scheme.

A. Otsu's Thresholding Technique

Otsu's method of thresholding [13], [8] is often cited in literature and for this reason we do not describe it in this paper. It is a global thresholding technique that works on the assumption that the gray level histogram of the image has a bimodal distribution and it iteratively selects an optimal threshold such that it minimizes the within-class variance of the two modes, or equivalently it maximizes the between-class variance. Despite being simple and parameter free the Otsu's method presents a limitation in its globality. An extension



(a) Sample number plate image (b) Windowing on gray image

(c) Global Otsu's binarization (d) Local Otsu'sbinarization

Fig. 1. Global and Local Otsu's binarization

of the global Otsu's is the local Otsu's thresholding method where the input image is divided into smaller sub-images of size $W \times W$ and the Otsu's thresholds are computed for each sub-image independently. Figure 1(a) shows a typical vehicle license plate image and the Figure 1(b) shows the sub-images using a window of size $W = 40$. Figure 1(c) and 1(d) show the resulting binarized image obtained using global and local Otsu's thresholding methods respectively. While the binarization is good for the local Otsu's, it is computationally more expensive than the global Otsu's because of multiple runs of Otsu's on all the sub-images. As will be shown later, typically the local Otsu's takes double the time compared to the global Otsu's. As an alternative, to retain the goodness of local thresholding and performance of global thresholding, we propose a new local thresholding method which uses local edge properties in a window to compute threshold which can be effectively used for text region extraction from the vehicle license plate images.

B. Local Edge Based Thresholding

Let an image foreground be represented by G_1 and background by G_2 gray levels and let $G_1 > G_2$. Typically the gray levels (Figure 2 for one row of such an image) between background and foreground change gradually. For binarizing such an image we should have a threshold G_T such that $G_1 \geq G_T \geq G_2$. A typical edge detection algorithm would mark edges at all or some of the locations marked by arrows in Figure 2. We exploit the edge image and use the edge pixels to identify the threshold (G_T) for binarization. A computationally simple way to compute G_T is to take the average gray value of the all the pixels on the edges. The steps involved in the proposed local edge based thresholding algorithm are given in the Algorithm 1.

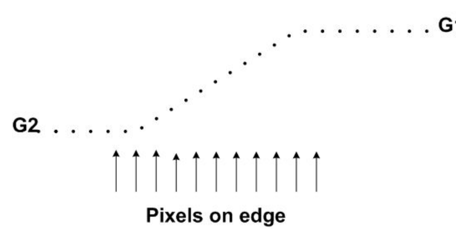


Fig. 2. Edge Detection in a gradually changing edge image.

Fig. 3. Binarized image using Algorithm 1

In the proposed algorithm *Step 4-5* calculates the threshold *only* if edges are present in a given window. When no edges have been identified (typically in a smooth gray image) there is no G_T computed. We set all pixels in this window to the binary value of the $(W/2, W)$ pixel of the previously processed window. Figure 3 shows the binarized version of the Figure 1(a) using the proposed method.

Algorithm 1 Edge based thresholding algorithm

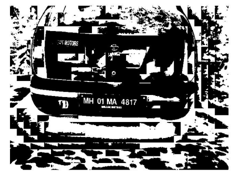
Step 1: Compute the edge image of the gray scale vehicle image. (We used Kirsch edge detection method in all our experiments)
Step 2: Remove small intensity edges (achieved by retaining the top 10% of the computed edges
Step 3: Divide the edge image into non overlapping windows of size $W \times W$. ($W = 40$ in all experiments)
while While traversing windows from top to bottom and from left to right when no more windowed image **do**
  Step 4: Check if any edges exist in the chosen sub-image
  if Edge Pixel Present **then**
    Step 5: Compute the average gray value by taking the gray values in the original image at the edge pixel location and set it to G_T for the window
    Step 6: Binarize the gray image in the window based on the G_T identified in *Step 5*.
  else
    Step 7: Set all pixels in the window to the binary value given by $(W/2, W)^{th}$ pixel of previous processed window.
  end if
end while

C. Binarization Experimental Results

Figure 4 shows a couple of vehicle images with license plates taken from our database. Figure 5 shows the binarization performed on Figure 4(a) using (a) Global Otsu's method, (b) Global edge based method, (c) Local Otsu's method and (d) Local edge based method respectively. Figure 6 shows the corresponding close up view of the license plate regions of the binary images. The better performance of local based methods compared to global based methods is evident in Figure 6. It can be observed that the global methods (both Otsu's and edge based) do not give separate connected components of all the characters in the license plate. In Figure 4(b) the license plate contains characters MH 14 BR 2814, but the characters identified by the global methods are only BR 2814 as shown in Figure 7. Whereas local methods (both Otsu's and local edge) give better results and retrieve all characters as separate connected components. Observe that among the global methods the characters are not well segmented in the Otsu's method whereas in the edge based method we get a few characters although with low quality in terms of solidity. But both local Otsu's and local edge methods gives all the character as separate connected components.

(a) Global Otsu's

(b) Global edge



(c) Local Otsu's

(d) Local edge

Fig. 5. Binarization results for vehicle image 4(a)

(a) Global Otsu's

(b) Global edge

(c) Local Otsu's

(d) Local edge

Fig. 6. Close views of license plate regions of images shown in Figure 5

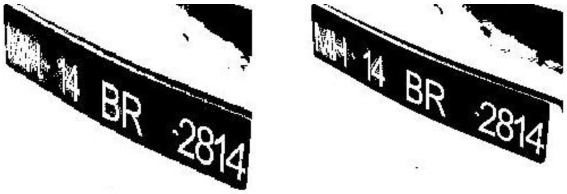
(a)

(b)

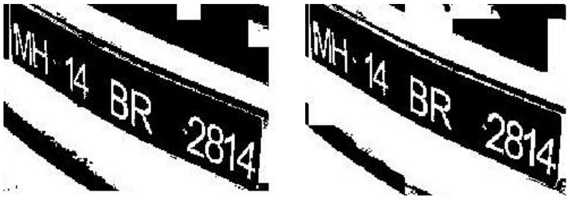
Fig. 4. Original vehicle images taken from the database

Also observe that the local Otsu's method is better than both the global thresholding techniques (global Otsu's and global edge based methods) but the proposed local edge based method performs better than local Otsu's method and additionally is computationally efficient. The proposed method performs well both in terms of being able to segment out the characters and computational speed. The speed comes because the algorithm does not have to process smooth images which have no edge information and the performance is because the edge pixels capture the pixels in the gray level transition region (see Figure 2).

Experiments are conducted to evaluate the proposed technique on a large set of real vehicle license plate images captured using mobile phone cameras. Post processing in the form of heuristic filtering is performed on the binarized images to eliminate non-text regions thereby retaining just the valid text regions. The binarization on vehicle image result in text and non-text regions. The text components (characters) have certain features which we can use for discriminating them from non-text components. We have defined a set of heuristic rules for filtering the non-text components based on different properties including area of the character component,



(a) Global Otsu's (b) Global edge



(c) Local Otsu's (d) Local edge

Fig. 7. Binarization of Figure 4(b) (a close view of license plate region)

(a) Nov. 24, 2010, 09.22:41 (b) Nov. 24, 2010, 18.07:30

Fig. 8. Vehicle images captured under different illumination conditions

aspect ratio, proximity to image frame, density, closeness to other components and contrast. Also the order in which these filtering rules are applied on the connected components in the binarized image [15], [16] is also very important. The vehicle images in our database also contain images captured under various illumination conditions (example, Figure 8, same car image taken in daylight and late evening). Figure 9 shows the performance of the edge based binarization on images taken in different illumination conditions. In a way the proposed edge based binarization method is invariant to lighting conditions.

III. Analysis on Character Extraction

We have analyzed the performance of the binarization followed by heuristic filtering based on 400 vehicle images from our database. In all there were 3945 text characters in

(a) (b)

Fig. 9. Binarization results (after heuristic filtering) of the images shown in Figure 8

TABLE I
Performance Analysis Results

Scheme	Total char.	Char. Extrat	Non-text Chars	Preci-sion	Recall	time (sec)
G.Otsu's	3945	2428	236	0.91	0.61	1.9
G.Edge	3945	2702	217	0.92	0.68	1.74
L.Otsu's	3945	3335	218	0.94	0.84	4.33
L.Edge	3945	3556	244	0.94	0.90	2.67

the chosen 400 images. For each of the four methods (Global Otsu's, Local Otsu's, Global edge, Local edge) we counted the number of extracted characters. Characters which are connected with other character or characters that were broken were not counted as correctly recognized characters. Precision and recall[1] has been calculated along with average execution time taken across all the images. The results are tabulated in Table I. It can be clearly seen that both precision and recall improve when local binarization methods are used compared to global methods. Local Otsu's and the proposed local edge based method perform closely in terms of precision and recall but the average time taken for computing is less than the time taken for local Otsu's method (compare 2.67 sec to 4.33 sec). The main advantage of the proposed method contributing to speed of computing is its non-iterative nature of computing the threshold also because of its dependency on local edge it does not perform any thresholding in smooth regions where as local Otsu's method tries to find thresholds even in smooth regions. Our observation showed that on an average only 70% of the windows were processed while binarizing the above set of 400 images.

We also conducted experiments to verify the performance of the binarization techniques on images of different resolutions to identify the performance deterioration with decrease in resolution. We specifically considered three different resolutions, namely, 160×120 (low resolution), 320×240 (medium resolution) and 640×480 (high resolution). The different resolution images taken using mobile phone camera is shown in Figure 10. We used windows (W) of size 10×10, 20×20 and 40×40 respectively for low, medium and high resolution for performing local binarization technique. Figure 11 shows the results of binarization (followed by heuristic filtering) for the images shown in Figure 10. The results of OCR applied on

(a) Low (b) Medium (c) High

Fig. 10. Original vehicle images of different resolutions

[1]These two terms are common in the information retrieval literature and hence not described here.

(a) (b) (c)

Fig. 11. Binarized vehicle images shown in Figure 10 using proposed method

these binarized images (where the actual license plate number is MH 03 S 7384) are tabulated in Table II. It is observed that at all the resolutions the edge based binarization performs better compared to the Otsu's binarization techniques.

TABLE II
OCR RESULTS FOR IMAGES WITH VARYING RESOLUTIONS

Res	Low	Medium	High
G. Otsu's	No output	MH05S7384	MH05S7384
G. Edge	ML03s Eb	MH03S7384	MH05S7384
L. Otsu's	ML03s Eb	MU0ss7384	MH05S7384
L. Edge	HHD3S7384	MH03S7384	MH05S7384

We used Tesseract OCR[17] for character recognition in all our experiments. We have segmented each connected component from the binarized images (after performing heuristic filtering) and fed to the OCR for recognition. The total number of text characters present in the set of 400 test images are 3945. The number of correctly recognized characters after performing Global Otsu's, Global Edge, Local Otsu's and Local Edge based binarization are 2035 (51.58%), 2280 (57.79%), 2820 (71.48%) and 2932 (74.32%) respectively. Clearly the edge based binarization scheme described in this paper performs better than all the other binarization methods, namely, the global and local Otsu's and also global edge.

IV. CONCLUSION

In this paper, we described a solution architecture to enable a mobile license plate recognition system. We proposed an edge based thresholding technique for binarization of an image to aid text region extraction from the vehicle images. Performance of the proposed edge based local algorithm has been compared with the well known and existing Otsu's binarization method and found that the proposed method performs better in terms of ability to preserve the text region and also on computational front. This system has been tested on a large number of real images captured under varying illumination conditions and resolutions. Experimental results show that the local Otsu's method and the proposed local edge based method perform equally well in terms of precision and recall, however the proposed method outscores in terms of computational time. We also evaluated the character recognition on the binarized image and found that the character recognition accuracy is higher for the proposed local edge based binarization technique compared to the other binarization schemes.

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