Real-Time Recognition of License Plates of Moving Vehicles in Sri Lanka

A.W.G.C.D. Wijetunge and D.A.A.C. Ratnaweera

Abstract- **Automated license plate recognition can be used for many applications such as detecting traffic light violations, access controlling, calculating parking fee and so on. However, detection and recognition of license plates can be seen as a complex problem. This paper presents an algorithm which can be used in Sri Lanka, for detecting and recognizing license plates automatically using image processing and neural networks techniques. In the proposed algorithm, the license plates are located by analyzing the regions with highest vertical edge density. Hough transformation and the affine transformation techniques are used to handle the skewed license plates. After extracting the license plate characters, a neural network is used to recognize those characters. The experimental results show that the proposed system can successfully detect and recognize all types of license plates in Sri Lanka and is suitable for real time implementation because of the lower execution time.**

Index Terms—Automatic License Plate Recognition, Hough Transform, Image Processing, Neural Networks

I. Introduction

License Plate (LP) is the primary identifier of a vehicle. Therefore, all the vehicles should have a well visible LP. LP recognition is one of the visual tasks that humans can do without much effort. Yet, this remains a challenge for computer systems.

Automatic License Plate Recognition (ALPR) is becoming significant in many traffic and security applications such as detecting traffic light violations, access controlling, calculating parking fee, tracking of stolen cars, etc. Researches in past have come up with various solutions for ALPR with varying degrees and complexities. But, the attention paid in this regard can be accounted as relatively less in the Sri Lankan context [1, 8] when compared with the other countries [2, 3, 4, 5, 6, 7].

The number of characters and the format of the LP can be recognized to be varied from country to country. Even within Sri Lanka various kinds of LPs can be seen [8]. Fig. 1 illustrates some of them. Some LPs have six digits, some have seven digits and also there are some LPs which contain digits along with English letters. Moreover, there are LPs with black colour characters on a lighter background as well as white colour characters on a darker background. The older versions of LPs contain the Sinhala letter "SRI" as a symbol.

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Therefore, it is necessary to come up with an ALPR system which covers all of the above formats of LPs available in Sri Lanka. But, past work on the ALPR in Sri Lanka has been focused only on the latest LP format [1].

In addition, each vehicle carries a single row LP at the front side where there is a double row LP at the rear side. In our previous attempt [8], both the above cases were handled using one algorithm. But, in the practical setup, the fixed camera will capture either the front LPs or the rear LPs. Therefore, here we split the algorithm into two separate algorithms to reduce the complexity by avoiding unnecessary checking and thereby reducing the execution time.

Most of the existing detection algorithms are based on colour based processing [1]. But, the rate of success of colour based methods highly depends on the lighting condition. Colour based methods are merely suitable for Sri Lanka, because there are LPs with different colour backgrounds. Additionally, different levels of illumination can be expected due to sunlight.

Moreover, LP detection is a challenging task since it has lot of obstacles such as uncontrolled background, skewed or rotated plates, damaged plates, etc. In Sri Lanka, various decorations can appear in the front and the rear view of the vehicle images and it makes the detection process more complex. Some LPs contain characters other than the LP characters (e.g., provincial code). Due to the variety of font types appear in the Sri Lankan LPs, the recognition of the LP characters is also a challenge. Only a few researches have been carried out to investigate the detection of LPs along with the recognition.

Therefore, it is difficult to adopt the existing systems directly for Sri Lankan LP recognition. The research issue of this study is to propose an algorithm to detect and recognize all the types of LPs in Sri Lanka with different conditions.

Fig. 1. Types of license plates available in Sri Lanka.

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II. METHODOLOGY

The proposed ALPR system comprises of five separate processing stages. First of all, the system processes a given image and roughly locates the potential LP regions. Then it detects and corrects the skew of the LP. As the third step, the LP is accurately located and verified. The extraction of the LP characters and numbers is done in the fourth stage. Finally, the features are extracted from the LP characters and recognition is carried out.

A. First Phase : Preprocessing

Set of preprocessing steps are carried out to improve the successful rate of the detection of LPs. At the beginning, the input image is converted into a grayscale image. After obtaining the grayscale image, median filtering is used to reduce noise. Then vertical edge detection Sobel kernel is used to extract the vertical edges from the image. Sobel vertical edge detection matrix is shown below (1).

$$\begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix} \tag{1}$$

Then potential LP regions are being located roughly by separating the regions with highest vertical edge density. Usually the contrast of the LP characters is higher than that of the plate background. As a result, the concentration of the vertical edges is high in the LP area. Since this can be identified as a key characteristic, the proposed algorithm is designed based on it.

The detection algorithms of [2], [4] & [6] are also designed based on the above characteristic. Reference [2] uses a method called Sliding Concentric Windows (SCW) to extract the LP regions. Since this SCW method is directly applied on the grayscale image, unacceptable amount of regions are extracted other than the LP region. Therefore, the execution time is high. Also, this method tends to fail when the LP is skewed or rotated. Reference [4] takes the horizontal and vertical projections of the vertical edge image to extract the LP region. If the LP is highly rotated or skewed, then these vertical and horizontal projections may not be useful to extract the LP region. Once the skew is corrected, these projections can be used to extract LP regions successfully. Reference [6] extracts the LP regions by grouping the line segments in the vertical edge image, which cannot be considered as a reasonable method and the execution time is high due to the complexity of the algorithm.

In the proposed detection algorithm, average filtering is used to obtain the vertical edge density image. Then, the vertical edge density image is thresholded using half of the maximum intensity value to extract the potential LP regions. Relatively Fig. 2, Fig. 3 and Fig. 4 include a grayscale image, the corresponding vertical edge image and the binary image containing the potential LP regions respectively.

Fig. 2. Grayscale image.

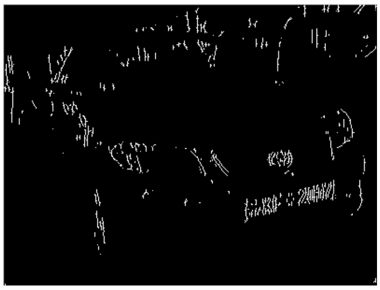

Fig. 3. Vertical edge image.

Fig. 4. Binary image containing the potential LP regions.

In our previous attempt [8], the potential LP regions in the binary image were processed from top to bottom. But, in contrast during this approach we process those regions from bottom to top because usually the LPs are contained in the latter part of the images.

B. Second Phase : Skew Detection and Correction

As a result of the positioning of the vehicle towards the camera, the roughly located LPs can be skewed in many ways. This is a place where most of the other related studies have not paid much attention on [1, 3]. It is very important to detect and correct this skew before segmentation of characters as it highly affects the success rate of the character segmentation and recognition. In this system, Hough transformation is used to determine the angle under which the plate is skewed. Horizontal edge detection Sobel kernel is used first to extract the horizontal edges in each roughly located potential LP region. Sobel horizontal edge detection matrix is shown below (2).

$$\begin{pmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{pmatrix} \tag{2}$$

Then the Hough transformation is applied to detect only the longest line segment in each potential LP region and to determine the angle. Here, we assumed that this longest line segment corresponds to the upper or lower horizontal boundary line of the LP. Therefore, the angle of the detected line corresponds to the skew angle of the LP. But there are some situations where there is no boundary line or the boundary lines are not clearly visible. In such situations, Hough transformation may not detect a line segment. Then the orientation of the object corresponds to the potential LP region is used as an approximation to the angle of skew in case if Hough transformation fails to detect any line segment. Reference [8] looks for two parallel lines and the Hough transformation used in [4] covers not only the longest one but all parallel lines together. It results in lower performance. Higher the number of parallel lines, slower the algorithm be.

Once the skew angle is determined, affine transformation can be used to correct it. If the LP is skewed by an angle θ, then the affine transformation can be used to de-skew the LP by using the following transformation matrix (3).

$$\begin{pmatrix} 1 & -\tan(\theta) & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad (3)$$

Reference [4] also uses this affine transformation matrix to correct the skew of the LPs. Fig. 5 illustrates the skew correction step.

C. *Third Phase : LP Localization and Verification*

LP localization task becomes easy after the correction of the skew. As the first step, the horizontal band containing the LP is detected and clipped. Vertical projection of the edge image of each skew corrected potential LP region is analyzed to detect and clip this horizontal band. Then the LP is localized by analyzing the horizontal projection of the edge image of each clipped horizontal band. Fig. 6 shows an accurately localized LP.

After the LP localization process, it is necessary to verify the correctness of selected LP regions by considering some basic features of a LP with which the false candidates can be discarded. The height to width ratio of a LP and two horizontal crosscuts are used in this verification process.

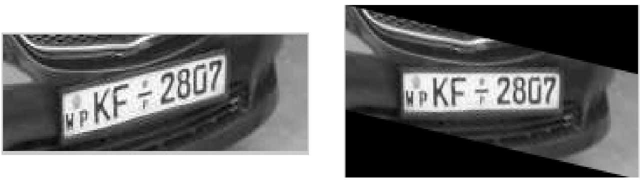

Fig. 5. Skew correction step.

Fig. 6. Accurately localized LP.

At this point our algorithm is being split into two, one is to handle single row LPs whereas the other one is to deal with double row LPs. Initially, we check the height to width ratio of LPs and select only the LPs which have a height to width ratio within a predefined range, as in (4).

$$\text{minRatio} < (\text{Height} / \text{Width}) < \text{maxRatio} \quad (4)$$

This "minRatio" and "maxRatio" values were obtained experimentally after analyzing all types of single row and double row LPs in Sri Lanka. LPs those do not satisfy the above condition are discarded from further analysis.

Next, two horizontal crosscuts are used on each vertical edge emphasized potential LP image and the number of objects that are cut by these crosscuts are counted. In this algorithm, a candidate will be verified as a LP only if the number of cut objects by each crosscut is greater than a predefined value which was obtained experimentally.

D. *Fourth Phase : Characters and Numbers Segmentation*

Once the system has identified and verified a region as a LP, it triggers the segmentation process. The purpose of this module is to isolate characters in the LP image and then to forward them to the next module. This segmentation should be done very accurately as it highly affects subsequent steps. For example, two characters can be merged together or a character can be divided into two pieces as a result of an unsuccessful segmentation.

Prior to all, the image is converted to a binary image using an adaptive thresholding method to separate the LP characters and numbers from the plate background. In this thresholding method, the plate image is divided into nine uniform rectangular areas and the local threshold value for each sub area is computed separately. Then the plate image is thresholded using those local threshold values.

The LPs in Sri Lanka can be further classified into two groups. One group contains the LPs with black colour characters on a lighter background (Fig. 7) whereas the other group contains LPs with white colour characters on a darker background (Fig. 8). Therefore, once the binary image is obtained, the system counts the number of objects in it and checks whether it is greater than 7 or not. If it is greater than 7, then the corresponding LP should have white colour characters on a darker background. But if it is less than 7, then the corresponding LP should have black colour characters on a lighter background. If so, the binary image should be inverted.

As the next step, the small objects are removed from the binary image. Then, the system performs set of operations on the resultant binary image in order to eliminate connected characters and characters connected with other unwanted spots in the background. This is a place where the existing systems have not paid any attention.

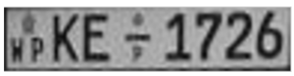

Fig. 7. LP with black characters.

Fig. 8. LP with white characters.

First, the system checks the number of white pixels in each row of the binary image. If that number is either too large or too small all the white pixels in that row are converted to black. If the width of the image is W, through a trial testing the following lower and upper bounds were selected (5), (6).

$$\text{Lower bound} = 0.1 * W \tag{5}$$

$$\text{Upper bound} = 0.8 * W \tag{6}$$

The basis for the selection of the above lower bound and the upper bound is that, in the binary image, if more than 80% of the pixels in a particular row are white colour pixels, then that row might be a part of an unwanted line. In that case, this upper bound is used to eliminate the unwanted lines in the binary image. On the other hand if just less than 10% of the pixels in a particular row are white colour pixels, then that might be a part of an unwanted spot and the above lower bound is determined to be a good limit to eliminate the unwanted spots in the binary image.

Subsequently, the system counts the total number of white to black and black to white pixel conversions in each row of the binary image. If that value is less than a predefined value all the white pixels in that row are converted to black. For single row LPs this value is set to 7 and for double row LPs this value is set to 4 after a trial test. All these operations are carried out in order to extract the LP characters more accurately from complex backgrounds. Fig. 9 and Fig. 11 show initial binary images whereas Fig. 10 and Fig. 12 show binary images after applying the above operations.

Next, the number of objects in the binary image is calculated and the height and width of each object is computed. Further processing is then done to check whether the area of each object is greater than a specified value and the height to width ratio of each object lies within a specified range. The height to width ratio of a LP character is approximately 2. In order to overcome misfit, it is set to a lower bound of 1.0 and 3.0 is determined to be a good upper bound for a LP character. The latest format of the Sri Lankan LPs contains two additional English characters which represent the provincial code. The height to width ratio of those two characters is similar to that of the other LP characters. Therefore, this ratio cannot be used to eliminate the characters in the provincial code. The only difference between the LP characters and the characters in the provincial code is that they are smaller than the LP characters. The area covered by each object in the binary image should be calculated to eliminate the provincial code. Finally, the objects those satisfy all the above constraints are cropped, resized and forwarded to the next module for feature extraction and recognition (Fig. 13).

Fig. 9. Initial binary image.

Fig. 10. Resultant binary image.

Fig. 11. Initial binary image.

Fig. 12. Resultant binary image.

Fig. 13. Extracted LP Characters.

E. Fifth Phase : Character Recognition

Once the numbers and characters of the LP are correctly extracted, then it is required to extract specific information from each character and number. This process is known as feature extraction. It is very important to extract the features accurately as it significantly affects the successful rate of the recognition process.

In our algorithm, a simple feature extraction method is used in order to identify the characters. First, each character is being resized into 14*10 pixel size and then the well known morphological thinning operation is used to obtain the skeleton of the character. Fig. 15 shows the skeleton of the character in the Fig. 14. The features are extracted from the characters using these skeletons. Therefore, after obtaining the skeleton image, its projection is taken on 16 different axes in such a way that each image pixel affects the projection only on 3 axes. The 16 different lines on which the projection is taken are illustrated in the Fig. 16. As mentioned earlier, one image pixel corresponds to three features. For an example, the image pixel P in Fig. 16 affects the projection on 2^{nd}, 5^{th} and 6^{th} axes only.

Lastly, the obtained features are applied to a multilayered feed-forward neural network trained properly using the back-propagation algorithm in order to recognize the extracted LP character. In this system, the training dataset was created in such a way that each number has at least ten copies.

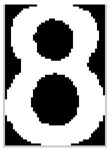

Fig. 14. Extracted Character.

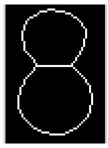

Fig. 15. Skeleton of the Character.

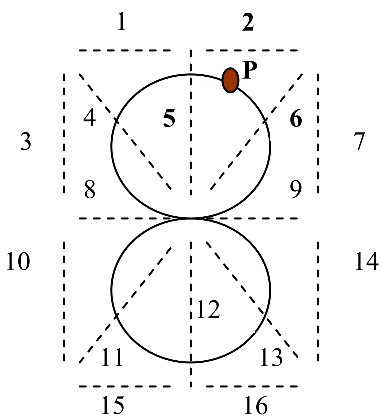

Fig. 16. Lines on which the projection is taken.

III. Results and Discussion

The software for this system was developed using MATLAB. Fig. 17 illustrates the graphical user interface of the proposed ALPR system. A database containing 120 colour images was used in order to evaluate the proposed algorithm. The database images were stored as JPG files of 300×400, 480×640 and 600×800 resolutions. Further, the image database contains vehicle images which are not clear and have complex backgrounds, which have been taken from different angles, which contain damaged LPs and which are taken from a long distance or a short distance.

Some of the successful LP detection results are presented below. Fig. 18 shows an image which contains a skewed LP. In Fig. 19 the colour of the LP itself is same as the colour of the vehicle and boundary lines of the LP are not clearly visible. Fig. 20 shows an image with a two row license plate. Moreover, Fig. 21 shows a successful detection of a LP which contains white coloured characters on a darker background and Fig. 22 shows the detection of a highly damaged LP. In all above situations, the system could detect the LP accurately.

The frontal view of the vehicle in Fig. 23 contains characters other than the LP characters which causes high vertical edge concentration in the vertical edge image. Therefore, those regions are also extracted as potential LP regions. References [4] & [8] gave false detection results in these types of situations since they process the images from top to bottom. Because of the reason that the LPs are in the latter part of the images, our novel ALPR system processes the regions from bottom to top and as a result of that it could detect the LP accurately in a lower execution time.

Fig. 24 illustrates a situation where our detection algorithm fails due to the complexity of the input image. LP characters in Fig. 24 are very small compared with the background. These types of situations can be overcome by taking the images from a shorter distance and also these situations should be dealt manually in an event of real time implementation of the algorithm.

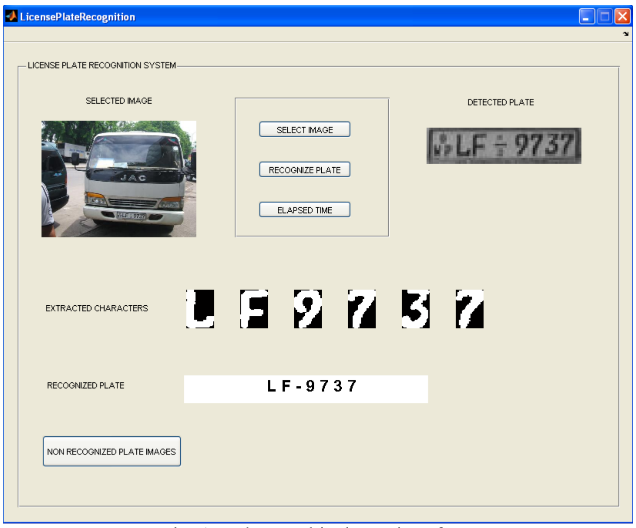

Fig. 17. The graphical user interface.

Some of the successful character segmentation results are presented in Fig. 25 and Fig. 26. Fig. 26 shows the character segmentation of a damaged LP.

Fig. 18. Detection of a skewed LP.

Fig. 19. Detection of a LP which does not contain any boundary line.

Fig. 20. Detection of a double row LP.

Fig. 21. Detection of a LP which contains white coloured characters.

Fig. 22. Detection of a highly damaged LP.

Fig. 23. Detection of a LP in a complex background.

Fig. 24. A situation where the detection algorithm fails.

Fig. 25. A character segmentation result.

Fig. 26. Character segmentation in a damaged LP.

Table 1 contains the independent results obtained from the three stages.

TABLE I
INDEPENDENT PERFORMANCE OF EACH STAGE OF THE ALGORITHM

Process	Success Percentage
LP Detection	97%
Character Segmentation	94%
Character Recognition	86%

The overall performance of the proposed system is progressive compared with the other related studies. It has a processing time ranged between 0.68s – 2.80s depending on the size of the input image.

Reference [8] presents its overall performance based on a test conducted using 90 car images. Although it shows a significant accuracy rate on those car images, some error LP detection results were encountered when different types of vehicle images were given to the system. For example, images of bikes, busses, trucks, three wheelers, etc with complex backgrounds. This especially takes place when various decorations and lines of characters appear in the front and the rear view of those vehicle images (Fig 23). But the novel ALPR system proposed in this paper works well for all types of vehicle images with complex backgrounds and also for all forms of LPs available in Sri Lanka. It gives better performance while reducing the execution time further.

Moreover, as we can not expect 100% accuracy in any real time application, the GUI of the proposed system facilitates to inspect the images manually in a case where system may failed to detect a LP.

IV. CONCLUSION

In this paper we have presented a real time LP detection and recognition system using image processing and the neural networks techniques. The significance of the proposed algorithm is proved by the results yielded out of it. The advantage of this method is that it works well for all types of vehicle images and for all types of LPs available in Sri Lanka.

The proposed system can deal with the images which contain the front view of a vehicle as well as the rear view of a vehicle. Since two algorithms are used separately for the two types, unnecessary checking could be avoided and as a result of that processing time could be reduced further.

Moreover, our algorithm is capable of achieving faster recognition in complex situations where most of the existing methods find it hard to detect and recognize LPs [1, 3]. For example, when the LP contains no boundary lines, when the colour of the LP is same as the colour of the vehicle, when some decorations or lines of characters appear in the front and the rear view of the vehicles, etc.

However, as a further improvement, to avoid errors in character recognition algorithm when dealing with similar characters, we recommend combining our detection algorithm with another character recognition algorithm which can recognize the similar characters more accurately in order to improve the overall performance.

Because of the lower execution time the proposed ALPR system can be regarded as suitable to be used in real time applications. Also, it has a higher applicability since we have not used any colour information in the implementation. Moreover, in an event of real time implementation, undetected plates should be sent for manual inspection.

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