A Malaysian Vehicle License Plate Localization and Recognition System

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ABSTRACT

Technological intelligence is a highly sought after commodity even in traffic-based systems. These intelligent systems do not only help in traffic monitoring but also in commuter safety, law enforcement and commercial applications. In this paper, a license plate localization and recognition system for vehicles in Malaysia is proposed. This system is developed based on digital images and can be easily applied to commercial car park systems for the use of documenting access of parking services, secure usage of parking houses and also to prevent car theft issues. The proposed license plate localization algorithm is based on a combination of morphological processes with a modified Hough Transform approach and the recognition of the license plates is achieved by the implementation of the feed-forward backpropagation artificial neural network. Experimental results show an average of 95% successful license plate localization and recognition in a total of 589 images captured from a complex outdoor environment.

Keywords: License plate, Hough Transform, Backpropagation, Localization, Character segmentation and recognition and Auto-skew correction.

1. INTRODUCTION

Generally, an automatic license plate localization and recognition (ALPR) system is made up of three modules; license plate localization, character segmentation and optical character recognition modules (Fig.1)
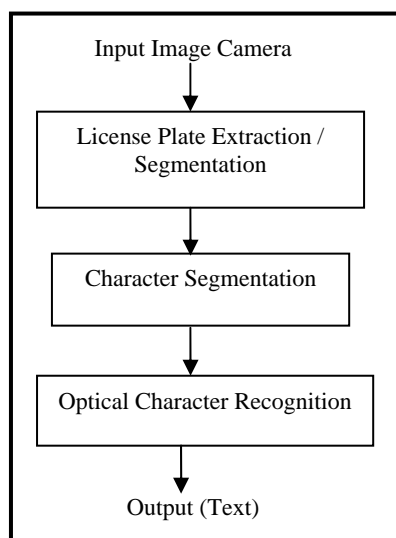

Fig. 1. Flowchart of a Typical ALPR System

The most common solutions to license plate localization in digital images are through the implementation of edge extraction, histogram analysis, morphological operators and Hough Transform. An edge approach is normally simple and fast. However, it is sensitive towards noise. Hough transform for line detection gives positive effects on image assuming that the plate is made up of straight lines. However, it requires the outline of the plate to be obvious for satisfactory license plate localization, large memory space and a considerable amount of computing time. On the other hand, a basic histogram approach is not capable of dealing with images with considerable amount of noise and tilted license plates. Last but not least, the localization of license plates via morphological based approaches is not susceptible to noise but is very slow in execution.

These techniques alone will not be sufficient to meet the requirements of modern systems. An intelligent license plate localization and recognition system today will be required to operate robustly in environments with complicated backgrounds and light intensity variations. To deal with such problems, researchers have proposed various solutions to address these problems. For example, Kim, S. et al [1] proposed a method based on edge extraction for license plate localization in images taken in poor lighting conditions. It consists of two steps. The first step involves the search of candidate regions from the input image using gradient information and the second step determines the plate area among candidates and adjusting the boundary of the area by introducing a plate template. On the other hand, Sarfraz, M. et al [2] utilized vertical edge detection and filtering which is then followed by vertical edge matching in the localization of Saudi Arabian license plates. As it is observed that images have more horizontal lines than vertical lines, this approach reduces computation time by detecting only vertical lines. In [3] and [4], additional edge extraction based approaches are discussed.

In the case of morphological based approaches, Dubey, P. [5] has improved morphological based approaches by modifying the conventional approach to yield a cleaner result on complex images by applying heuristics. Alternatively, Wu, C. et al [6] combine morphological operations and a projection searching algorithm for vehicles in Macao The projection searching algorithm is used to detect region of the characters in the license plate through vertical and horizontal projections. The license plate styles found on vehicles in Macao is very much similar to the ones found in Malaysia and this can be a solid reference.

After the localization of the license plate comes the character segmentation process. Common character segmentation processes are based on histogram analysis and thresholding. Other recent approaches proposed are such as the use of artificial neural networks to determine the optimum threshold value by Fukumi, M. et al [7], the utilization of the Gabor transform and vector

quantization by Kahraman, F. et al [8] and template matching by Song, H. et al [9].

The final stage of this system is the character recognition process. Wu, C. et al [6] and Naito, T. et al [10] adopted the template matching method which can be easily implemented. However, to deal with the number of variations found on the characters across different license plates will require the segmented character to undergo some preprocessing steps such as normalization and skew correction. These additional steps prove to be beneficial as it greatly reduces the required computation time. For example, Sarfraz, M. et al [2] improves the template matching by normalizing the characters prior to template matching. The more advance techniques include the use of neural networks [10, 11] and self organizing maps [12].

2. AN OVERVIEW OF THE SYSTEM AND ITS CORE CONCEPT

The primary software used in this work is Matlab R2006a (v. 7.2). The core components of the software used are the Image Processing Toolbox (IPT) and the Neural Network Toolbox. An Intel Pentium 3.0 GHz dual core processor with 1Gb memory is used to execute the software and a Sony DSC-P10 digital camera (Fig. 2) is used to capture the 589 digital images. Digital images obtained are of one mega pixel resolution without the use of any of its additional features. This is done on purpose such that the experimental results can be able to validate the robustness of the proposed algorithm.

Fig. 2. Sony DSC-P10 Digital Camera

The history of the automatic license plate recognition system is quite exhaustive and many have been successfully implemented for commercial usage. However, setting up a license plate recognition system in Malaysia does not only require the system to deal with conditions such as illumination variation and soiled and skewed license plates. It also requires the system to deal with the non-standardization of license plate styles in Malaysia. To enable the system to operate robustly under such an environment, an algorithm which is based on the combination of morphological processes and a modified Hough Transform approach is developed.

Normally, the Hough Transform is used to locate the vertical and horizontal borders of a license plate. This is clearly illustrated in the work of Tran, D. D. et al [13]. The group has combined Hough Transform with the Contour Algorithm which is used to detect closed boundaries of objects. This technique reduces memory space and computation requirements. However, it will not be applicable for the localization of license plates in Malaysia. This is primarily due to the fact that most license plates found on Malaysian vehicles do not have a clear border and the white characters fall on a black background which is not as distinctive as the yellow or white background colors which can be found in license plates of other countries. Thus, the core concept of the license plate localization process developed for this system is purely based on the features of the characters rather than the borders of the license plate. This is due to the fact that the characters are the more distinctive objects on the license plate.

The localization, character segmentation and recognition modules will be discussed in the following sections. Then, the results will be analyzed and discussed before this paper is concluded.

3. LICENSE PLATE LOCALIZATION

As being highlighted in the previous sections, the license plate localization process is a combination of morphological processes with a modified Hough Transform approach. To be able to work with morphological processes, it is normally more convenient to convert the original RGB image into a grayscale image and subsequently into a binary image. The Otsu's global thresholding method [14] is applied in this system to convert the grayscale image into a binary image. This technique suggests minimizing the sum of within class variances of the object and background pixels to establish an optimum threshold. The result of this global thresholding method will normally yield binary images as shown in Fig. 3.

Fig. 3. Outcome of Otsu Thresholding Method

As shown in Fig. 3, it can be clearly seen that the characters of the license plate have been properly segmented from its background. This is then followed by the execution of various morphological processes and the modified Hough Transform approach on the binary images. The license plate localization module is then completed by the auto-skew correction and candidate evaluation processes which are discussed in the following subsections.

Morphological Processes
The morphological processes which are applied onto the image aim to remove all unrelated objects in the image and ensure that the characters on the license plate are well preserved. However, to ensure that the algorithm is robust enough to cater for characters of varying sizes and scale, a number of morphological processes will be applied to the image. This is performed to ensure that a

loose upper and lower limit is specified for each process. Based on the measured properties of the objects, it will be checked upon the relevant upper and lower limits specified to determine whether it remains or is to be removed from the image. There are three main morphological processes applied to the image. The width, height and number of holes of each individual object of the binary image are checked. Those exceeding the specified upper and lower limits will be removed from the image. This is then followed by the fill, clear boundary objects and small objects removal processes. Fig. 4 clearly illustrates these processes.
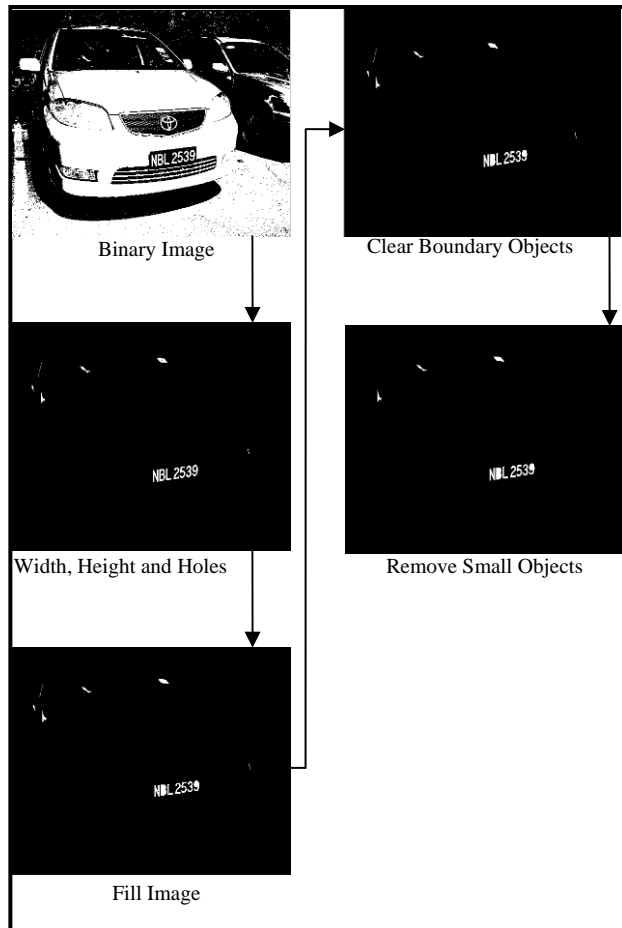

Fig. 4. Morphological Processes Flowchart

Modified Hough Transform Approach
As mentioned before, the Hough Transform is normally applied to detect the borders of the license plate. In this system, the focus has been directed to the characters of the license plate instead. In most cases where Hough Transform is applied, the input image is normally an edged image. Then, the horizontal and vertical lines of the license plate borders will be located. However, in this system, an edged image will not be required. In contrast, the Hough Transform is directly applied onto the resultant output of the morphological processes such that the features of the characters are preserved. As usual, once the Hough Transform of the image is obtained, the peaks are then located. The located peaks correspond to the location of the straight lines in the image and it is then plotted against an empty binary image (all 0's). The pixels which are taken up by these lines will be converted from zero valued pixels to a value of one in this empty binary image. The lines found intersecting among one another form an object. This will eventually allow the location of the borders of this object to be retrieved easily. Thus, by retrieving the properties of the bounding box of all intersecting lines in the image, the candidate regions bounded by these lines are obtained and can be subsequently displayed on the original image. Fig. 5 illustrates the modified Hough Transform approach.

In order to ensure satisfactory results from this approach, it is very important to properly specify various parameters such as the threshold value to locate the peaks on the Hough Transform, the number of peaks to be detected and the minimum and maximum length of lines to be detected.
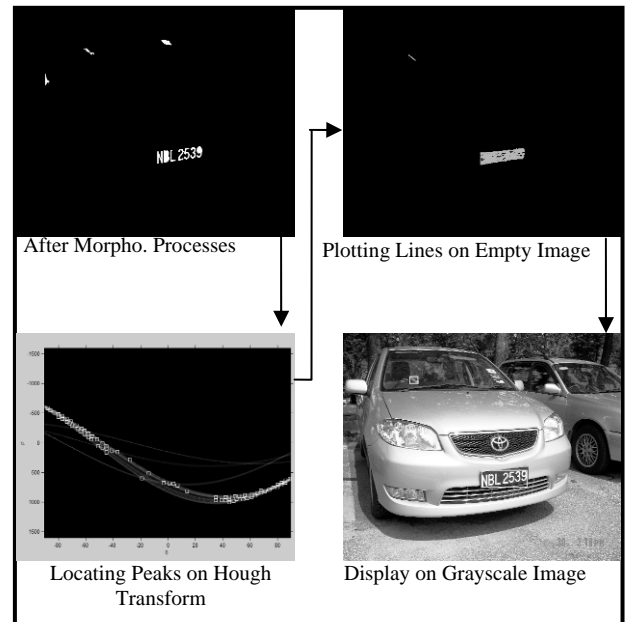

Fig. 5. Modified Hough Transform Approach Flowchart

If too many lines were to be detected, then it may result in a slow process. Vice-versa, if the number of lines to be detected is far from optimum, it might not provide a candidate region that covers the entire license plate. As such, the desired configuration is to have the entire license plate extracted with the minimal number of lines. As noted, there will normally be more than one candidate region. Prior to the candidate evaluation process, the auto-skew correction process is executed.

Auto-Skew Correction
The main objective of the auto-skew correction process is to improve the candidate evaluation process and the rate of successful recognition for the character recognition module. The developed auto-skew correction process is also based on the Hough Transform. The resultant candidates of the modified Hough Transform approach are the inputs to this process. Fig. 6 shows some sample candidates which contain the license plate.

From these samples, it can be observed that after extraction is successfully performed, there are still some undesirable objects which remain in the image after the first stage of morphological processes. To remove such objects a second set of morphological processes which consists of a bounding box filter which is then followed by fill and small objects removal in the candidate. Take note that this second operation does not include the clearing of boundary objects to avoid characters from being removed.

Fig. 6. Sample Candidates

In the case of applying the Hough Transform to perform the auto-skew correction process, the resultant image from the second morphological process is edged by applying the Sobel operator. Similarly, the peaks which correspond to the location of straight lines are located on the Hough plot and the detected lines are drawn onto the edged image. The line of interest is either the topmost line (on the upper edges of all characters) or the bottom-most line (on the bottom edges of all the characters). These two lines will facilitate the calculation of the angle of rotation of the license plate with respect to the horizontal axis.

In this system, the bottom-most line is chosen as the line of interest. As such, for all candidates, the bottom-most line will be located. To locate this line from all the lines identified from the Hough plot will require the establishment of several criteria. The most obvious property of the bottom-most line is that it should have the largest average y-coordinate value from its start and end points (Matlab coordinate system for images). However, there may be situations whereby the presence of some foreign objects in the candidate region causes this line of interest to lose this property. The presence of these foreign objects is mainly due to the failure in removing it in the second morphological process. As such, in order to handle such situations, the length and gradient of each line will be taken into consideration as well. After the successful location of the bottom-most line, the angle of the plates with respect to the horizontal axis can be calculated by applying simple trigonometry rules. Fig. 7 illustrates the auto-skew correction process.
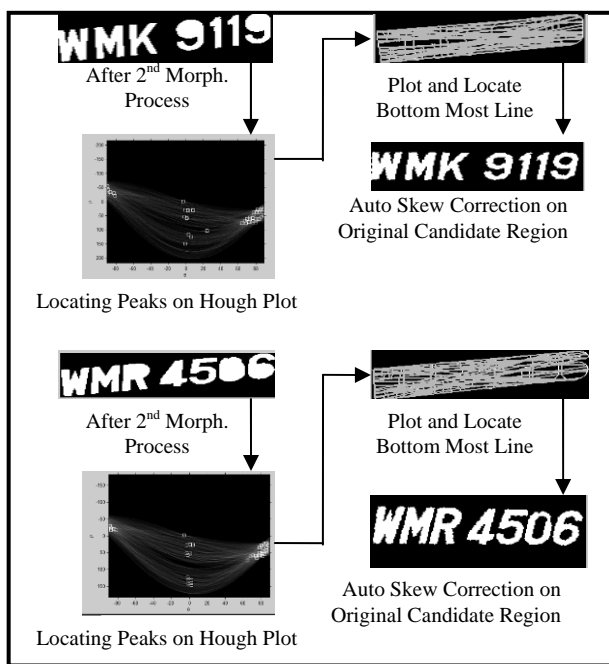

Fig. 7. Auto-Skew Correction Process Flowchart

Candidate Evaluation

As being described in the previous subsections, the modified Hough Transform approach normally locates more than one candidate region (illustrated in Fig.8). To determine the correct candidate region which contains the license plate will require the candidates to undergo some evaluation process. The evaluation process is made up of several tests to check the likelihood of each candidate region to contain the license plate. Only the one which passes all these tests will be regarded as a license plate. These tests are the width to height ratio and number of holes and objects of the candidate regions. The 3 proposed tests are normally capable of removing most of the false candidate regions. However, there are cases where these false candidate regions are not detected. As such, the vertical projection analysis is adopted as the final evaluation procedure.

Fig. 8. Samples of False Candidate Regions

The vertical projection analysis is implemented based on the parallel beam projection of the Radon Transform at zero degrees. The vital part of this evaluation is the automation of the analysis process. Fig. 9 and 10 will compare the signature of a license plate region as compared to a signature of a false candidate region.
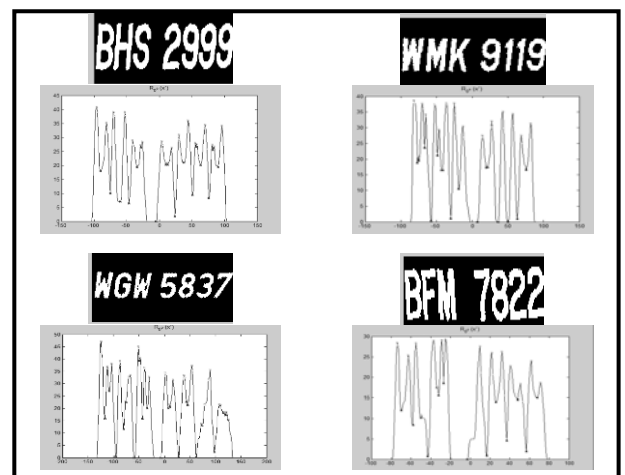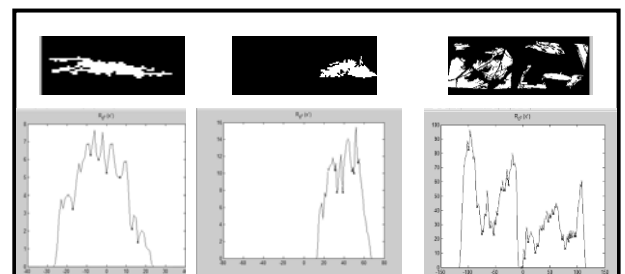

Fig. 9. Signature of a License Plate

Fig. 10. Signature of a False Candidate Region

Simple regions as shown on the first two false candidates on the left of Fig. 10 can be easily removed by using a simple algorithm. However, for the identification of more complicated false regions will require something more reliable. After the vertical projection of each candidate is obtained, three types of points will be located

by the proposed algorithm; trough, peak and tracked points. The proposed algorithm is as follows:

(i) Locate all peaks and troughs
(ii) Take the first peak, p_i as the reference point.
(iii) Take the following peak, p_{i+n} as a second reference. (where 'n' starts from 1)
(iv) Locate the minimum point between the two reference peaks and mark this point as a trough point.
(v) Calculate whether the trough point between these two peaks is less than 30% of the reference peak.
(vi) If true, consider this as a track point, increment 'i' by 1 and reset 'n' to 1. If false, increment 'n' by 1 and proceed to step (vii) if 'i+1' is equivalent to the total number of peaks. For both cases, repeat step (iii) until all candidates are evaluated.
(vii) Calculate the number of track points located and decide whether the candidate is a license plate region.

4. CHARACTER SEGMENTATION

The character segmentation acts as a bridge between the license plate extraction and optical character recognition modules. Its main function is to segmentate the characters on the chosen candidate region such that each character can be sent to the optical character recognition module individually for recognition. Looking closely at the white characters which fall on a black background on Malaysian license plates indicate that thresholding will be a very convenient tool for the purpose of character segmentation. On the other hand, the license plate localization module has already been working with binary images. Thus, this results in the extracted license plate to be already in the desired form. To extract the characters on the license plate will only require the location of the bounding box of each object in the chosen candidate region. Then, for each extracted bounding box, the object with the maximum area is retained. All other objects are removed. Fig. 11 illustrates the character segmentation process.
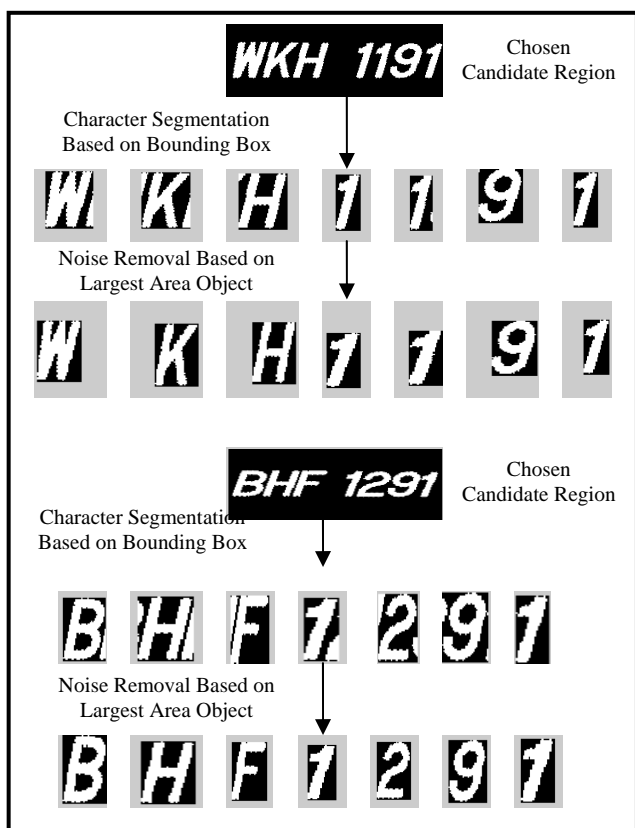

Fig. 11. Character Segmentation Process Flowchart

Prior to character recognition, the characters are normalized into a size of 25x15 pixels. This fixed normalization process is performed to allow the recognition of the segmented characters via artificial neural networks in the character recognition module.

5. CHARACTER RECOGNITION

The primary approach in the development of this module is the utilization of the feed-forward backpropagation artificial neural network. As the neural network can only accept a fixed nx1 array as its inputs, it clearly explains the need of the character normalization process. With a character size of 25x15 will imply the neural network to have 375 neurons on its input layer. A 3-layer neural network is developed following the rule of thumb. This rule suggests that the number of neurons in the middle layer to lie in between the number of neurons between the input and output layers. The proposed neural network output format is as illustrated in Fig. 12. As such, this suggests that the output layer should consist of 36 neurons. The numeric characters from 0-9 and letters A-Z make up this sum. However, the letter 'I', 'O' and 'Z' cannot be found on any license plates in the database of images. As such, the neural network for this system only consists of 33 neurons. A sample of characters ranging from 0-9 used in the training process can be found in Appendix A.

A	B	C	D ....
1	0	0	0
0	1	0	0
0	0	1	0
0	0	0	1

Fig. 12. Neural Network Output Format

By experimenting with various configurations, it is found that the neural network which is trained by the gradient descent with momentum and adaptive learning rate backpropagation algorithm with 375 neurons on its input layer (pure linear activation function), 204 neurons on its middle layer (tangent sigmoid activation function) and 33 neurons on its output layer (pure linear activation function) yields the highest rate of successful recognition. The network is thoroughly tested with both trained and untrained data in order to validate its robustness. These training samples are obtained from the 589 images in the database. The structure of the proposed neural network is as illustrated in Fig. 13. This network produces satisfactory results with minimal training time. As such, it will be very convenient to include additional characters.
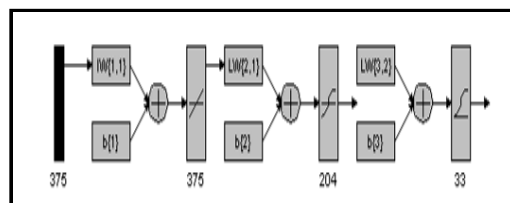

Fig. 13. Neural Network Structure

6. RESULTS AND DISCUSSION

To facilitate in the validation of the robustness of the proposed algorithm, a simple Graphical User Interface (GUI) is developed through the use of the GUI Development Environment toolkit (GUIDE) in Matlab. Fig. 14 shows the developed GUI for the system. The user can easily import the images into the GUI, locate the license plate and segmentate and recognize the characters on the license plate. Furthermore, the user can check the various

checkboxes on to the GUI to look into the resultant output images of the various processes highlighted in the previous sections. Fig. 15 illustrates the output of the vertical projection analysis on the two candidate regions detected.
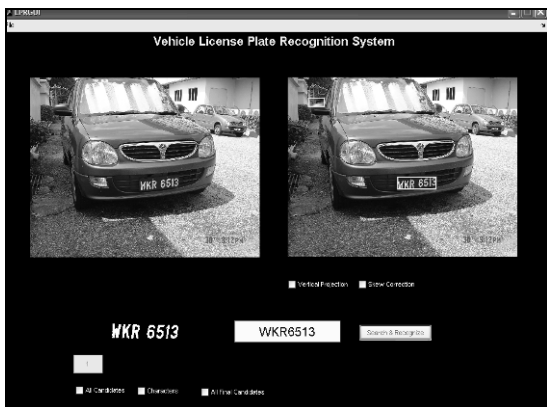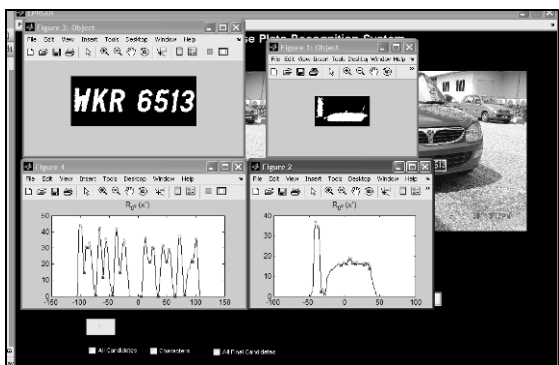

Fig. 14. Graphical User Interface

Fig. 15. Vertical Projection Analysis of Candidates

A total of 589 digital images have been used to test the proposed algorithm. An average of 95% in successful license plate localization and recognition on the complex outdoor images are recorded. These images are made up of vehicles positioned in different orientations, varying light intensity and located in front of a complex background. In a controlled environment, the accuracy of localization and recognition is close to 100%. Fig. 16 shows the results of 4 images selected from the database with the license plate successfully localized and recognized. For more sample results, please refer to Appendix B.

It is observed that the 5% unsuccessful localization and recognition is a result of license plates which contain metallic characters or characters which do not have a clear separation. Characters which are too close to one another will be impossible to separate by means of simple character segmentation algorithms. More complicated algorithms on the other hand may impose a heavier burden on the processor and will require the algorithm to be intelligent enough to know the point of separation between two or three characters which are joined together and form an individual object. Obvious solutions to this problem is to utilize high resolution images which will directly increase the computational requirement of the algorithm or to simply ensure that the image is taken at a distance and viewpoint that ensures sufficient separation of the characters on the license plate.

Although the use of Hough Transform is well known to impose large memory requirements and considerable amount of computing time, however, this may be worthwhile for its reliability. Moreover, powerful processors are becoming more and more affordable nowadays. In addition, the execution of this

algorithm can be even more efficient if it is converted into a standalone C program.

Fig. 16. Sample Images in Database

The proposed algorithm further includes an auto-skew correction process which helps to achieve the required character recognition accuracy and an automatic vertical projection analysis in search of the candidate which contains the license plate. These processes do not only complete the license plate localization process but also ensures the high rates of successful license plate localization. A higher priority is normally given to the license plate localization process as its reliability affects the robustness of the entire system. Nevertheless, to be practical for commercial applications, it will require all modules in the system to operate robustly.

7.   CONCLUSIONS

From the experimental results, the proposed algorithm for the license plate localization and recognition process of the system has already satisfied the demands of a commercial car park system in Malaysia. In the development of this system to cater for Malaysian vehicles in mind, the proposed license plate localization process has taken a different approach to identify the location of the license plate through the combination of morphological processes and a modified Hough Transform approach which focus on the characters features rather than the borders of the license plate. Although the system now operates on digital images taken from a camera, it can be easily applied to an actual system. Further work is in progress to implement this algorithm into a complete system which consists of a camera system suitable for this type of application and a third party software such as Microsoft Access to create and maintain a database of registered vehicles.

8.   REFERENCES

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9.   APPENDICES

Appendix A. Sample Training Characters (0-9)
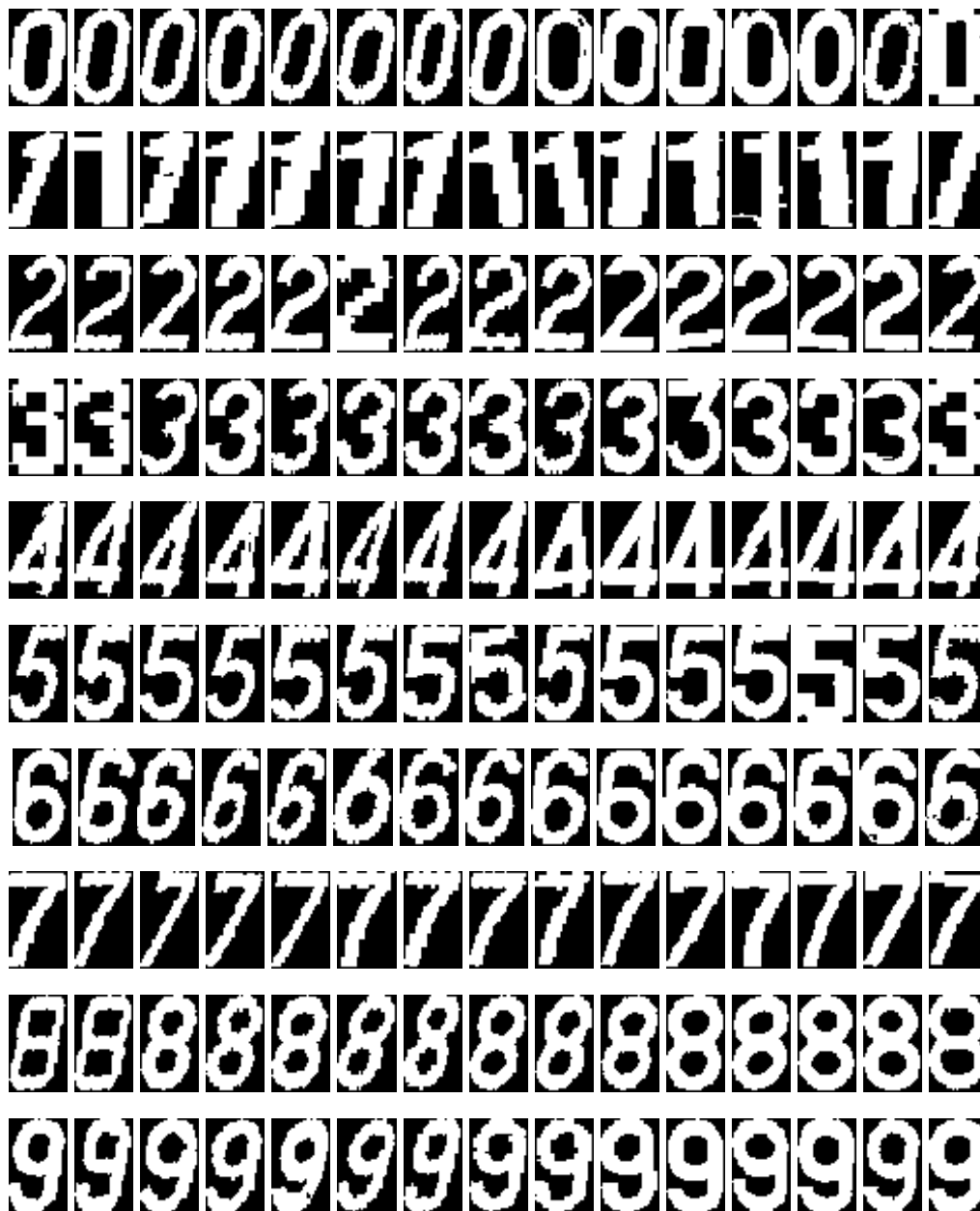
Appendix B. Results of other images collected in the database