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Comparative Study of Malaysian License Plate Recognition Systems

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Abstract: License Plate Recognition (LPR) system is a special type of Intelligent Transport System (ITS). It is used to identify and recognise car plate registration numbers. However, the LPR system's performance is still an issue. This is due to different countries apply different standard plates, besides other influenced factors such as noises and illumination. The aim of this study is to compare the proposed algorithm with the recent studies on Malaysian LPR systems to investigate how such factors would affect the system performance in plate recognition. The finding proposes that the smearing algorithm is the most suitable algorithm to be implemented in Malaysian LPR system.

Key words: Intelligent transport system, license plate recognition, image processing, Malaysian LPR systems, smearing algorithm, implemented

INTRODUCTION

License Plate Recognition (LPR) is one of the major research areas in the field of Intelligent Transport Systems (ITSs). The LPR system fully depends on image processing to identify and recognise license plates registration. It has been implemented in various ITS applications, especially, in traffic monitoring systems as well as for public protection security systems. These systems which include toll road payment collection system, parking management system and LRP mobile based application system are used to assists law enforcement agencies to detect stolen or wanted cars.

The system's performance in term of accuracy is crucial to ensure that the LPR system will be successfully implemented in these applications. There are many factors including license plate standardization, noise, illumination, distance and tilt angle as well as plate size that can influence the performance of the LPR systems (Bakhtan *et al*., 2016). Failure to appropriately handle these factors may reduce the efficiency and accuracy of the license plate recognition process.

Regarding license plate standardization, different countries apply for a different standard of license plate registration which makes this research to be very much country-oriented. In Malaysia, based on the specification by Jabatan Pengangkutan Jalan (JPJ) Malaysia, the license plates can be classified into standard and non-standard plates. The standard group is displayed in an italic font style whereas the non-standard group uses a non-italic font style. The plate is also designed either based on a single row and double rows format (Anonymous, 2016). There are various algorithms that have been developed in LPR system. Nevertheless, the LPR system's performance still requires significant improvements in order to be used in an unrestricted and natural environment. This study reviews the performance of the proposed algorithm with the recent studies on the LPR systems in Malaysia and examines the factors that influenced the plate's recognition process in order to identify the most suitable algorithm to be applied in Malaysian LPR system.

Background: There are various algorithms that have been proposed in the field of image processing, specifically, in LPR systems. To achieve a high accuracy of license plate recognition is a challenging task due to several reasons including the variations in plate types as well as the nature of the environment (Bakhtan *et al*., 2016). This section reviews close-related studies on license plate recognition algorithms including Edge Detection (ED), Support Vector Machine (SVM), Optical Character Recognition (OCR), Feed-Forward Neural Network (FNN) and Smearing Algorithm (SA).

The Edge Detection (ED) is one of the most commonly used algorithms in image processing. An edge is a boundary between an object and its background within images. The shape of edges in an image relies on numerous parameters for instance the geometrical and optical properties of the object, the illumination conditions and also the noise level in the image (De Sousa Matos and de Souza, 2012). The ED algorithm is simple and can easily detect the object boundaries of a license plate, provided the edges are not broken or missing (De Sousa Matos and de Souza, 2012) has proposed a hybrid of ED.

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Table 1: LPR algorithm comparison

Methods	Pros	Cons
ED	Simple, fast and able to find the object which dimension is like a license plate	Hardly succeeds if the edges have been broken, missed or not found
SVM	Has ability to detect license plate even if the boundary is deformed	Complex and sensitive to noise
OCR	Widely used to automate the tasks and that do not require human intervention Ability to import reading to the robot that recognises the plate number	Time consuming because it has to read all characters Produces detection errors when there is another text in the image
FNN	Implemented easily Fast identification speed High precision and accuracy of the technique, which works irrespective of the colour, size, location and angle	Weak recognition when similar characters exist, e.g., Z &2,o&0,5&S, etc
HE	Fast, considerable accuracy that can be improved when working with another algorithm	Time consuming while detecting (ROI)
SA	Straight forward Independent of the license plate position and design Suitable for Malaysia car plate number format	Weak colour detection

and histogram equalization to improve the recognition rate and has been implemented in Indian license plate recognition system. The main area of this study is the segmentation part. The result of the recognition rate is 89% in terms of accuracy. However, the proposed algorithm is sensitive to the angle and environment.

The SVM has been proposed by Parasuraman and Subin (2010) that classification is powerful in reducing training and testing time where parameter tuning could be generated automatically. However, SVM employs quadratic functions which are complex and always correspond to the loss of the functions. Thus, to increase the recognition rate in such cases, it has to be combined with two or more algorithms. For example, by Bhosale *et al.* (2014), template matching with the combination of SVM and Feed Forward Neural Network (FNN) are successfully used to recognise Indian license plate with 96% recognition rate. One of the advantages of this study, for the template matching stage is that it uses digits of 0-9 and alphabets of a-z and A-Z.

The OCR deals with the problem of recognising optically processed characters. In optical recognition, the characters have to be printed before the process started. It is unlike on-line recognition where the characters are recognised as they are drawn. Although, it could recognise both hands printed and printed characters, the performance still relies on the quality of the input documents (El Gajoui and Allah, 2014). Based on previous studies, the OCR algorithm has been used to recognise plate numbers and it is useful in a character recognition process which is the last process for the LPR system. It has the ability to detect and recognise the characters from an image (Dhruw and Roy, 2014).

The major advantage of the FFN algorithm is the high accuracy of the technique in the plate's recognitions process (Angeline *et al.*, 2012). In license plate recognition system, FFN has contributed to the improvement of the system's performance. It seemed to be more efficient in detecting the texture and colour features by using the number of edges in the plate area. The HE contributes to the selection of the Region of Interest (ROI), it is also the most common algorithm used for segmentation by using a vertical and horizontal image. Even though the region growing method takes a lot of the computation time, it would produce a considerable accuracy (Wang *et al.*, 1999).

In Angeline *et al.* (2009), SA has been proposed for Malaysia plate recognition and used in the detection process. Smearing is an action of applying something by spreading or daubing. It is used for text areas extraction on a mixed image. By using the SA, the image is processed along with the vertical and horizontal runs (scan-lines). As this algorithm is manually set in the programme as a threshold value, the pixel of the gap in the image is restricted to a certain value (Du *et al.*, 2013). This enables the SA to search for the first and last white pixels which starts from the top left corner of an image. The image will then be cropped by leaving only the vehicle's plate number.

Table 1 shows a summarized comparison of the LPR algorithms. Also, it illustrates the pros and cons of each algorithm to come up with a comprehensive overview of the most popular algorithm's features as well as to identify the most suitable algorithm which is SA for detecting and segmenting the Malaysian plates. In this research as the threshold value can be controlled within a predefined range, it is high likely to obtain a successful detection. Furthermore, SA has many additional features compared to other algorithms. For example, the edge detection can only detect a rectangular area with definitive edges while SA does not rely on the edges of the plate region. SA uses a logical calculation to calculate the number of pixels which is then compared to the predefined threshold to identify the plate location.

MATERIALS AND METHODS

This study discusses the proposed algorithm in the LPR system's components. The LPR system consists of three main components which include pre-processing,

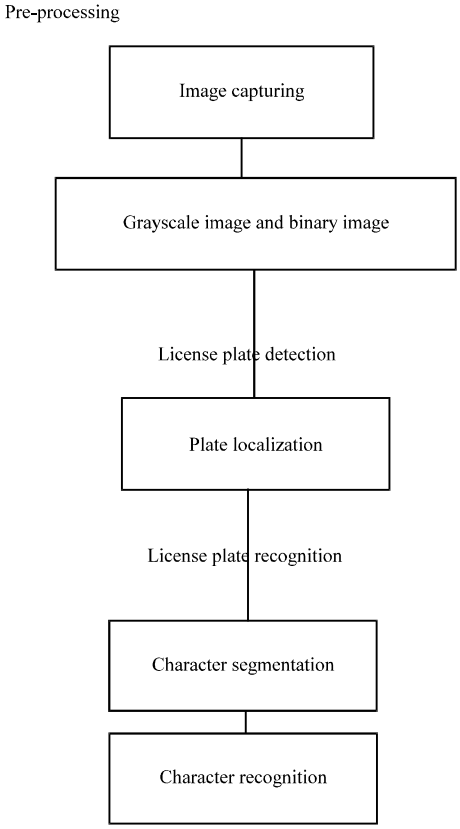

Fig. 1: LPR system's component

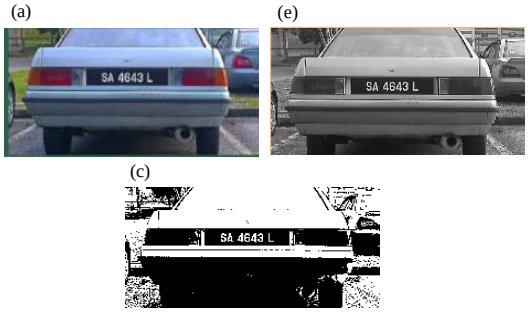

Fig. 2: Preprocessing processes (preprocessing): a) Image in RGB format; b) Greyscale image and c) Output binary image

detection and recognition. The flow of the processes in each of the component is illustrated in Fig. 1. In the pre-processing component, three processes are involved to convert the source image to binary image as shown in Fig. 2. First, the image is captured and saved in RGB format. Second, it will be converted into a greyscale image. These two processes are essential to enhance the quality of the source image where the numbers of pixels

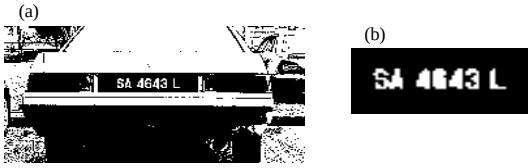

Fig. 3: Detection process (detection): a) Binary image and b) (Output) plate location

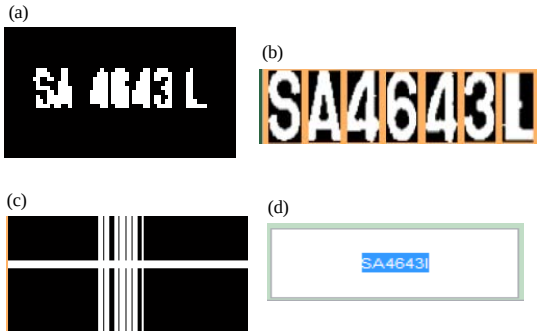

Fig. 4: Recognition processes (recognition): a) Plate localization; b) Plate localization; c) Character Segmentation process and d) Segmented characters, plate pecognition

are reduced using the greyscale technique. Finally, the image will be converted to a binary image to simplify the license plate location process, thus, decreases its processing time.

In the detection component, it involves license plate localization process as shown in Fig. 3. The aim is to detect the area of the license plate called the Region of Interest (RIO). There are several steps involved including filtering to eliminate noises, dilation, erosion, convolution, flood fill, cropping and lastly, ROI detection using Smearing Algorithm (SA). The SA scans the plate region horizontally and vertically to find the exact location of the license plate.

There are two processes involved in the recognition component which include character segmentation and character recognition as illustrated in Fig. 4. The character segmentation process is used to separate every single character using SA algorithm. The plate region is segmented based on the character's location. In this process, each sample image is divided into seven regions and each region represents one segmented character.

The last process is character recognition. The final outputs from this process are generated by comparing the segmented characters with the characters in the database using template matching and cross-correlation function.

The result is considered successful, if the generated characters are equal to the segmented characters. On the other hand, the character recognition process is considered a failure if there is no match found.

RESULTS AND DISCUSSION

This study discusses the characteristics of the proposed algorithm and compares its performance with recent studies on LPR systems in Malaysia. There are many factors that influence the recognition process of Malaysian license plates. Few studies Angeline *et al.* (2011), Bakar *et al.* (2012), Soon *et al.* (2012), Sulaiman *et al.* (2013), Keong and Iranmanesh (2016) and Khaleel *et al.* (2013) highlighted one or more of these factors such as light, shadow and illumination, image distance and angle and motion pictures. There are however, still other unstudied factors that could affect the performance of plate recognition. Table 2 summarizes the outcomes of the comparison study. In this study, Abdullah *et al.* (2017), a wide range of Malaysian license plates characteristics were covered including single and double rows plates and standard and non-standard plates. It also investigated the effect of various factors such as noise and clarity of image, size of plate and characters, illumination and darkness, tilt angle and the distance between the camera and the license plate. Table 2 presents the results obtained from this study.

The results showed that the study conducted in this research is more extensive and comprehensive in three major aspects as follows:

Includes double rows plates: Angeline *et al.* (2009) have proposed the smearing algorithm to be used in the detection process but it was not successful when applied on double rows plates, in the segmentation process. In this study, the same algorithm was proposed and applied on both single and double rows of Malaysian license plates. In contrast, it has been successfully implemented in the segmentation, detection and recognition of both single and double rows of plates with comparable quality.

Includes non-standard plates: Furthermore, most of the existing studies did not include the non-standard Malaysian plates in their investigations. Only Ng *et al.* (2015) addressed the special Malaysian license plates. The proposed algorithm, in contrast, studied in details both standard and non-standard license plates. The results demonstrated that the non-standard plates have a significant effect on the recognition process of Malaysian license plates.

Solving the character similarity issue: The similarity issue between some pair of characters was addressed and solved in this study. The proposed algorithm has

Table 2: LPR systems comparison

References	Methods	Includes double row	Includes nonstandard plates	Effecting factors included	Character similarity issue	L%	S%	R%	Overall
Angeline *et al.* (2012)	FNN	No	No	None	Fixed (2, Z), (5,S), (8, B)	92	85	90	70
Angeline *et al.* (2009)	SA&TM	Unsuccessful	No	None	Unsuccessful (8, B),(E, F), (0, D), (5, S) and (2, Z)	-	-	-	-
Angeline *et al.* (2011)	FNN	No	No	Distance shadow light	No	-	-	-	-
Bakar *et al.* (2012)	ED	No	No	Light	No	86	86	-	-
Soon *et al.* (2012)	CCA	No	No	Motion picture	No	98	95.9	93.6	88
Ng *et al.* (2015)	ED&OCR	No	No	None	No	-	42	52.4	22
Al-Ghaili *et al.* (2012)	VEDA	Yes	No	None	No	9189	-	-	-
Chai *et al.* (2014)	OCR&ED	Yes	Yes	None	No	-	-	-	64&51
Abdullah *et al.* (2017)	Smearing algorithm	Yes	Yes	Noise-illumination-distance-tilt angle-size of plate and characters	Fixed (B, 8), (G, 6), (O, 0), (Z.2) and (S, 5)	97.4	96	76	71
Halin *et al.* (2013)	OCR	No	No	Black and white background	Unsuccessful (1.7)	-	-	-	-
Keong and Iranmanesh (2016)	Template matching	No	No	None uniform illumination	No	100	99.6	91.5	91.1
Khaleel *et al.* (2013)	SURF	No	No	Motion picture	No	8191	-	-	-
Ng *et al.* (2015)	ED	No	Yes	None	No	81	-	-	-
Yogheedha *et al.* (2018)	OCR	-	No	Light	Unsuccessful (2, Z)	-	-	-	-

successfully fixed the confusion and misclassification between five pairs of characters which are (B, 8), (G, 6) (O, 0), (Z, 2) and (S, 5). There are some other studies such as (Angeline *et al*., 2009, 2012; Sulaiman *et al*., 2013) that addressed this similarity issue. However, the only study in Angeline *et al*. (2012) was able to fix the similarity between the three pairs (2, Z), (5, S) and (8, B) while studies by Angeline *et al*. (2009, 2012) and Yogheedha *et al*. (2018) were unsuccessful to address this issue.

The previous studies used SA in the detection process only with edge detection to detect plate numbers. However, in this study, SA is used in both detection and segmentation processes to improve the accuracy of the license plate recognition system. This research has achieved good results on both single-row and double-row plates. In addition, by applying smearing many times, this research has resolved the similarity problem between some characters and numbers such as the following pairs: (2, Z), (8, B), (5, S), (6, G) and (0, O).

Moreover, Table 2 shows that most of the existing Malaysian license plate recognition studies did not include sufficient and detailed performance results of each part of the recognition process. For example, Bakar *et al* (2012), Al-Ghaili *et al*. (2012), Halin *et al*. (2013), Khaleel *et al*. (2013) and Ng *et al*. (2015) did not provide performance results and success rates of all stages of the recognition process. Some other studies, Al-Ghaili *et al*. (2012), Halin *et al*. (2013) and Khaleel *et al*. (2013) focused only on the detection process without implementing or investigating other processes such as segmentation and recognition. While, Bakar *et al*. (2012), however, implemented detection and segmentation processes only. Studies Angeline *et al*. (2009, 2011) and Sulaiman *et al*. (2013) provided incomplete performance measurements of each process.

Overall, the proposed algorithm outperformed many of the existing algorithms (Angeline *et al*., 2012; Simin and Mei, 2013; Chai *et al*., 2014) in terms of success rate and extensiveness of the study. However, there are two studies Soon *et al*. (2012), Keong and Iranmanesh (2016) have achieved a higher success rate, 88 and 91.1%, respectively. By Keong and Iranmanesh (2016), the algorithm was tested using 100 images and video samples. While by Soon *et al*. (2012), the algorithm was tested using 270 sample images. However, both studies did not include the double rows and non-standard Malaysian plates. Furthermore, the similarity issue between some characters was also not addressed or solved in these studies.

Also, only non-uniform illumination factor was included and investigated by Soon *et al*. (2012) while the proposed algorithm has investigated five other affecting factors that have significant impacts on the overall success rate of the plates recognition. It is important to notice that the inclusion of many affecting factors in a license plate recognition system greatly impacts the overall success rate of the system.

CONCLUSION

In this study, the SA algorithm has been proposed for Malaysian LPR system. This study investigated several factors that would influence the accuracy in plate's recognition including various plate characteristics and environmental nature. This study has shown remarkable results compared to other existing studies. It has also shown a comparable performance to those studies, although, more affecting factors are used in the investigation. Finally, this study successfully solved the similarity issue between some pairs of characters. The finding proposes that the smearing algorithm is considered as the most suitable and convenient algorithm for detecting and segmenting the Malaysian plates.

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