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Bounding Box and Thresholding in Optical Character Recognition for Car License Plate Recognition

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Abstract: License plate recognition plays a central role in a variety of application contexts, including traffic management, automated parking, and law enforcement. Among the various approaches available, the Optical Character Recognition (OCR) technique has proven its effectiveness in recognizing characters in license plate images. This study describes an approach for detecting and recognizing vehicle license plates by utilizing the OCR method with Bounding Box, Thresholding, and template matching. In addition, this study uses MATLAB R2022a software as the main tool in developing and implementing the method. The goal is to recognize vehicle license plates from images, describe their characteristics, and generate relevant information. This approach involves a series of image processing steps starting with the pre-processing stage, followed by the process of binarization and license plate segmentation. After successfully isolating the license plate area, isolating the character using a bounding box is performed using image separation techniques. The OCR method is used to recognize license plate characters through comparison using the correlation method. Through a series of experiments on several image datasets, this approach succeeded in showing that out of 20 sampled license plate images, the results obtained were a reading accuracy of 93.55% of 100%, recognizing 13 out of 20 license plate images accurately when tested. In the second test, testing was carried out using sample images that were given a grain filter to make them look blurry, the results of the reading accuracy were 82.5% of 100%, recognizing 9 out of 20 images accurately. Thus, the findings of this research are expected to contribute to the recognition of vehicle license plates that are accurate and efficient, by utilizing image processing techniques and OCR methods implemented using MATLAB R2022a software.

Keywords: *Bounding Box, License Plate Recognition, Optical Character Recognition (OCR), Template matching, Thresholding*

INTRODUCTION

Vehicles and license plates have an important role in various aspects of modern life. Vehicles are a means of transportation that enables efficient mobility of people and goods. Various types of vehicles such as motorbikes, trucks, cars, and bicycles have a vital role in connecting places that are far apart. Along with the growth of vehicles, the importance of accurate identification of each vehicle is also increasingly emphasized. A vehicle number plate, or what is often called a registration number, is a unique identifier given to each motorized vehicle. This number plate consists of a combination of numbers, letters, or symbols that form a certain code. The main function of license plates is to provide clear identification of vehicles, facilitate administration and traffic control, and support law

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enforcement. Therefore, license plate recognition has an important value in improving the security, efficiency, and management of transportation in various contexts. In this context, this study aims to develop a character recognition system on vehicle license plates using the Optical Character Recognition (OCR) method (Memon et al., 2020). The primary goal of this study is to generate and implement a method that can recognize characters on vehicle license plates with high accuracy.

In recognition of license plates using the OCR method, this technology is the core of the process of identifying the characteristics of license plates. By adapting image processing and text analysis technology, the OCR method enables the conversion of characters on license plates into text data that can be processed by a computer (Gnanaprakash et al., 2021). This results in the ability for automation to detect, recognize, and record information from vehicle number plates quickly and accurately, this is one of the advantages of OCR. This technology has great potential in applications such as law enforcement, traffic management, automated parking, and security. Researchers have used various techniques and methods in vehicle license plate recognition, referring to various sources such as journals, books, and conference papers. They collect relevant information from previous research to understand the various approaches that have been applied before. Research (Etomi & Onyishi, 2021), discusses the Automatic Vehicle Number Plate Recognition System (ANPR) using several OpenCV Digital Image Processing (DIP) techniques developed with the Python programming language to generate image segmentation from which multiple image segments are tested for characters, so that the length of the characters found on each segment with properties similar being the key to localizing and intersecting territory with actual vehicle license plates. Once the region is acquired, OCR is used via templates trained for several character styles to derive the text format of the license plate. The developed work has 100% plate localization accuracy and 90% reading accuracy.

In research (Kusumadewi et al., 2019) this discusses the template matching method in character recognition in OCR. The steps described include pre-processing with gray image conversion, median filtering, and dilation; character segmentation to cut license plate characters; image size normalization; and the recognition stage using the normalized correlation function. Derived from the outcomes of the conducted tests, the accuracy reaches 80%. These three studies involve various steps of pre-processing, character segmentation, and recognition using template matching and image processing techniques to automatically recognize vehicle license plate characteristics. However, in addition to the approaches mentioned, this study also includes feature extraction to further describe the characteristics of license plate images. Feature extraction is a technique that helps identify patterns or special characteristics in an image(Humeau-Heurtier, 2019). This extraction feature can help improve the understanding of the image and unique characteristics of license plates, which can be important in the character recognition process.

Based on the literature from several related studies, OCR is able to recognize characters on license plates with satisfactory accuracy. Based on the capabilities possessed by OCR, in this study, OCR was implemented in the recognition of car license plates with dataset limitations in the form of black license plate images with white writing on both motorcycle and car types of vehicles. Experimental testing has been carried out using accuracy. Further discussion can be seen in the next section.

METHOD

The methodology used in character recognition research on vehicle license plates uses the Optical Character Recognition (OCR) method with the template matching approach and the bounding box technique. This methodology is designed to achieve the research objective of identifying characters on vehicle license plates with high accuracy.

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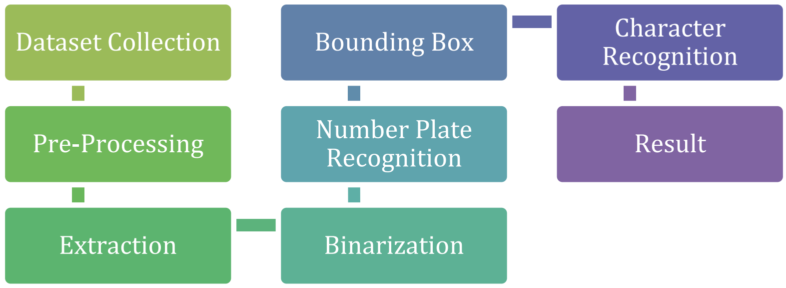

Fig. 1 Processing and license plate recognition steps for the proposed system.

Dataset

License plate datasets are obtained from open sources such as Kaggle and Roboflow. Our dataset has been collected using several sources, such as https://www.kaggle.com/datasets/andrewmvd/car-plate-detection and https://universe.roboflow.com/ranias-workspace/dataset-plat-nomor. This kind of dataset includes a collection of vehicle license plate images taken during daytime conditions with adequate lighting and an object acquisition distance of about one meter. Within this dataset, license plate colors are indicated on a white background and black text, creating a clear visual contrast. Figure 2 shows the 20 license plate photo samples used in this study.

Fig.2 Sample Number Plate Image

Pre-processing

At the pre-processing stage, a crucial first step in the Optical Character Recognition (OCR) process, there are numerous techniques used to prepare vehicle images before further analysis. First, the image conversion is performed from RGB format to grayscale (grayscale). This aims to remove irrelevant color information and simplify the image into a single gray level, which will then facilitate character recognition. In addition, the image size is also rearranged to achieve a more suitable dimension. With these steps, the image is well prepared for the next stage in the OCR process, which involves segmentation and character recognition of license plates.

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The binarization stage is an important step in recognizing vehicle license plates. At this stage, the resized gray image is evaluated to convert it to a binary image (Agrawal et al., 2020), where there are only two-pixel values: black (0) and white (1). This process begins with calculating the threshold using a certain method, namely the Thresholding Otsu method (Hamdoun & Mentagui, 2022), which allows separation between the object (number plate) and the background. After the threshold is determined, the pixel values in the image are changed to black or white based on their relationship to the threshold. The result of the binarization stage is a clear and sharp binary image, which facilitates the subsequent phases within the process of recognizing license plate characters.

After the binarization stage, the next step is the number plate detection stage. At this stage, the resulting binary images are analyzed to identify areas that may contain vehicle license plates (Selmi et al., 2020). The methods used may involve techniques such as edge detection, morphological operations, or contour analysis to isolate areas that have similar shapes and characteristics to license plates (Wu et al., 2022). This process aims to focus attention on relevant areas in the image and ignore unimportant elements. The result of the detection phase is the area indicated as a potential number plate, which will then be the focus of the next process.

The next stage in the license plate recognition system is the bounding box stage (Jamtsho et al., 2020). Once potential areas containing license plates have been identified, this step involves applying bounding boxes to each of these areas. This bounding box surrounds the area deemed to contain license plate characters with higher precision (Huang et al., 2021). This approach enables precise isolation of the characters present on the license plate, thereby preparing the image in a more structured form and ready for the character recognition stage. The use of Bounding Boxes can facilitate the process of further analysis in subsequent stages, and character recognition through the template matching method or other character recognition algorithms.

Extraction

The extraction stage is a step that has been used in the process of recognizing vehicle license plate characters using the OCR method (Shashidhar et al., 2021). After the vehicle image After the vehicle image has been pre-processed, this step aims to extract the important features that can distinguish the characters on the license plate. In the program presented, feature extraction is performed on the resized image that has been processed into a gray image. This feature extraction provides an overview of the pixel intensity distribution in the image, which can assist in the process of recognizing license plate characteristics more accurately. characters on the license plate. In the program presented, feature extraction is performed on the resized image that has been processed into a gray image. This feature extraction provides an overview of the pixel intensity distribution in the image, which can assist in the process of identifying license plate characteristics more accurately. The aim is to extract important features that can distinguish the characters on license plates. In the program presented, feature extraction is performed on the resized image that has been processed into a gray image. This feature extraction provides an overview of the pixel intensity distribution in the image, which can assist in the identification of license plate characteristics more accurately (Zhang et al., 2021). These features can then be used as a numerical representation of the characters on the license plate, enabling the selection of the most suitable character through the matching method with pre-trained template characters. Several extraction features such as average pixel value (mean), skewness, standard deviation (SD), kurtosis, variance, entropy, maximum pixel value, and minimum pixel value are extracted from gray images using predetermined calculation methods. To get the average value (mean), calculations are performed with the following formula:

$$M = \frac{\sum_{i=1}^{n} x_i}{n} \quad (1)$$

Where n is the number of elements in the dataset, and x_i is the value of the i element in the dataset.

To get the standard deviation value, calculations are carried out with the following formula:

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$$std = \sqrt{\frac{\sum_{i=1}^{n}(x_i - m)^2}{n}} \tag{2}$$

n is the number of elements in the dataset, and x_i is the value of the i element in the dataset, and m is the mean value of the dataset.

To get the kurtosis value, calculations are carried out with the following formula:

$$k = \frac{\sum_{i=1}^{n}(x_i - m)^4}{n \times std^4} \tag{3}$$

Where n is the number of elements in the dataset, and x_i is the value of the i element in the dataset, and m is the mean value of the dataset, and std is the standard deviation of the dataset.

To get the variance value, the calculation is carried out with the following formula:

$$variance = \frac{\sum_{i=1}^{n}(x_i - m)^2}{n} \tag{4}$$

Where n is the number of elements in the dataset, x_i is the value of the i element in the dataset, and m is the mean value of the dataset.

To get the Skewness value, the calculation is carried out with the following formula:

$$Skewness = \frac{\sum_{i=1}^{n} (\mathcal{X}_i - \bar{\mathcal{X}})^3}{n \cdot \mathcal{S}^3} \tag{5}$$

Where n is the number of elements in the dataset, x_i is the value of the i element in the dataset, and m is the mean value of the dataset and $\mathcal{S}$ is the strander deviation of the dataset.

To get the Entropy value, the calculation is carried out with the following formula:

$$Entropy = -\sum_{i=1}^{N} p(x_i).\log_2 \tag{6}$$

n is the number of possible values that are in the distribution or dataset, x_i is the value of the element i in datasets, and $p(x_i)$ is the probability of occurrence x_i in distribution.

To get the Minimum value, the calculation is carried out with the following formula:

$$Min = min\ (x_1, x_2, \ldots, x_n) \tag{7}$$

Where n is the number of elements in the dataset, and x_i is the value of the i element in the dataset.

To get the Maximum value, the calculation is carried out with the following formula:

$$Max = max\ (x_1, x_2, \ldots, x_n) \tag{8}$$

Where n is the number of elements in the dataset, and x_i is the value of the i element in the dataset.

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Character Recognition

At the character recognition stage in the license plate recognition system, the isolated characters are compared with the character templates using the template matching method (Lin et al., 2019). This method uses cross-correlation (Vaishnav & Mandot, 2020) to evaluate the resemblance between the characters that underwent testing and the patterns stored in the database. Characters with the highest correlation are identified as recognition, enabling effective recognition of license plate characters based on similarity to a template. The cross-correlation formula is as follows:

$$R_{xy}[m] = \sum_{n} x[n] \cdot y[n+m] \quad (9)$$

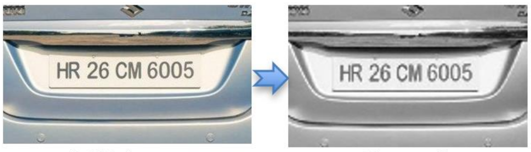
Where $[m]$ is the correlation between the two images and $R_{xy}[m]$ is the cross-correlation function between $x[n]$ and $y[n]$ on shift $[m]$.

Result Target

The result of the car license plate recognition system using OCR (Optical Character Recognition) is output in the form of text that represents the characters on the vehicle's license plate. This output can be a sequence of characters that have been identified and reconstructed from the original license plate.

RESULT

The initial process begins with reading the image data that has been analyzed. Next, the image is resized to dimensions of 300x500 pixels for consistency in the analysis. if the image is color (RGB), it is converted to a grayscale image using the 'rgb2gray' function. This process can be seen in Fig 3.



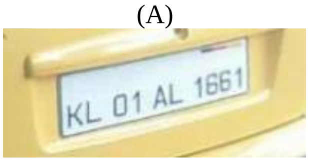
RGB image Grayscale

Fig 3 RGB image to Grayscale

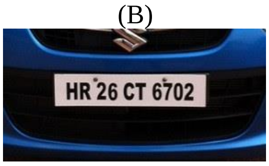
In images that have been resized and converted to gray images, feature extraction is performed to average the pixel value (mean), kurtosis, variance, skewness, standard deviation (SD), entropy, maximum value, and minimum value in Fig. 4 to determine the distribution of pixel intensity in the image. The results of the extraction are shown in Table 1 based on Images in Fig. 4

(A)

(B)



(C)



(D)

Fig. 4 Sample of Extracted Number Plate Image

Table 1. Extraction Feature Results

Number plate	Extraction Feature							
	Mean	Standard Deviation	Kurtosis	Variance	Skewness	Entropy	Min	Max

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A	167.774	51.7253	3.03051	2675.5	-0.363709	7.30546	7	255
B	99.1241	70.3063	1.79833	4942.98	0.585137	7.41451	5	255
C	216.635	23.8142	3.93682	567.115	-0.861904	6.33321	100	254
D	64.4981	52.847	3.61689	2792.81	0.07142	7.26768	0	255

The next step is to perform image binaryization using the Otsu thresholding method. This binarization process transforms the grayscale image into a binary representation, where components with intensities above the threshold will be converted to white (1) and those below the threshold to black (0). Small components in binary images with less than 30 pixels are removed using 'bwareaopen'. Fig 5 displays the outcomes of the Binarization procedure.

Fig. 5 Image After Binarization

The next step is license plate detection. Done by utilizing information about the width of the image. If the image width exceeds a certain threshold (2000 pixels), a larger area threshold is used to remove smaller connected components and focus on license plate identification. Conversely, if the image width is smaller, the lower bound area is used. After this step, only the component representing the license plate area remains on the drawing. In this case, license plate recognition comes into focus.

The next step is to isolate the text component on the license plate. This is achieved by subtracting a binary image containing the entire license plate from a binary image that exclusively includes the license plate components. The result of this step is a binary image containing only the text on the license plate. During this stage, the text component on the license plate is labeled using the labeled connected component technique. This function is used to label each connected component, and information about the bounding box for each component is obtained using the 'regionprops' function. Next, the bounding box around the text component is drawn on the original image using the 'rectangle' function. The results of implementing the Bounding Box are shown in Fig 6.

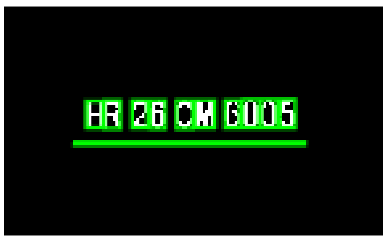

Fig. 6 Bounding Box image

Then the isolated characters are resized to a predefined reference size to facilitate comparison. Character recognition is done by comparing the correlation between isolated characters and reference characters using the 'corr2' function. A character is considered recognized if its correlation value exceeds a specified threshold (0.45 in this case) and the result is shown in Fig. 8. The template used in this study is shown in Fig. 7.

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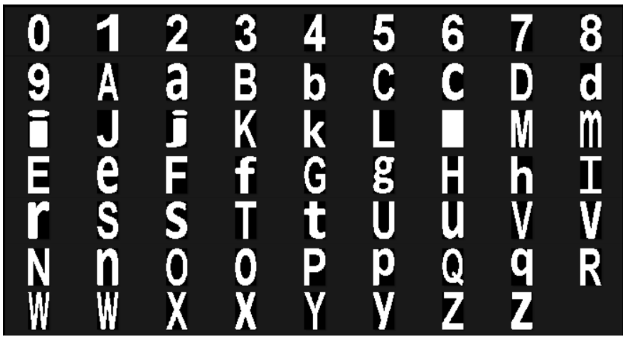

Fig.7 The template matching used

Based on Fig 6, there are 52 characters for the template matching database consisting of 10 numbers templates, 26 uppercase, and 26 lowercase. After the results are known for the correlation value. Subsequently, identify the column where the correlation value exhibits the greatest outcome.

Fig.8 The final result

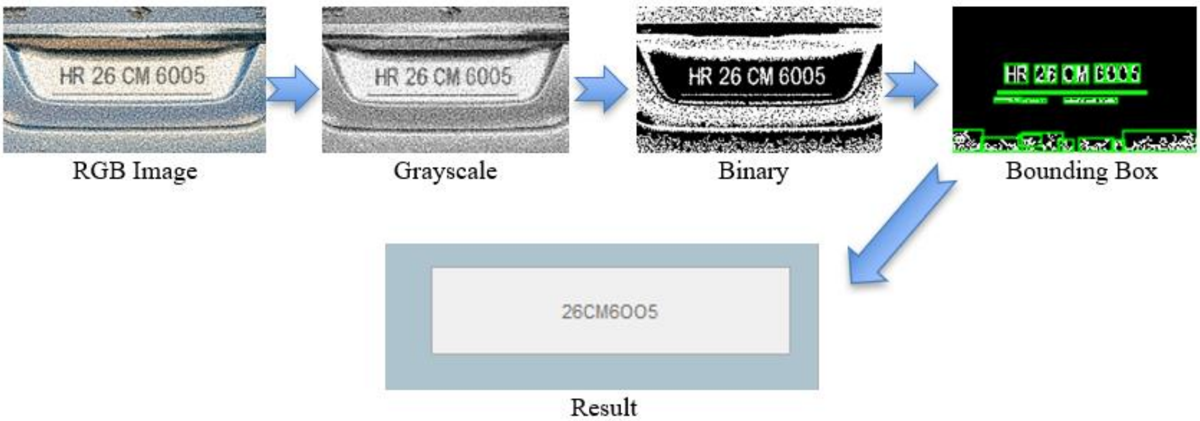

Fig. 9 Low-resolution image

Another tested has been done using blur and low-resolution with grain filter dataset as shown in Fig 9. Based on this low-resolution image, testing was carried out and the accuracy results obtained were 80%. 8 of the 10 characters license plates can be detected accurately. In Fig 9 the expected result is HR26CM6005, but only 26CM6005 can be detected. This explains that images with low resolution or blur cannot be detected accurately and a higher resolution is needed so that all the characters on the license plate can be read accurately.

Table.2 Result of Number Plate Recognition

Image	Plate Number	Using original images		Using blur images (Grain filter)	
		Result	Accuracy	Result	Accuracy
Plate1	KL 01 AL 1661	KL O1 AL 1661	90%	01AL11	60%
Plate2	DL 12 CG 6648	OL12CG6648	90%	OL1268	50%
Plate3	DL3C BR7476	DL3C BR7476	100%	DL3CBR7476	100%
Plate4	MH20CS4946	MH20CS4946	100%	R20CS4946	80%

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Plate5	ALR486	ALR4BB	67%	ALR46B	67%
Plate6	TN74AH1413	TN74AH4J3	80%	TN74AH1A	70%
Plate7	HR26DA0471	HR2DAO471	80%	RDAO471	60%
Plate8	HR 26 CM 6005	HR26CM6005	100%	26CM6005	100%
Plate9	HR 26 CH 3604	HR 26 CH 3604	100%	HR26CH3604	100%
Plate10	KL01BR8055	KL01BR8055	100%	XL01BR8055	90%
Plate11	HR26CT6702	HR26CT6702	100%	HR26CT6702	100%
Plate12	GJW115A 1138	GJW11GA1138	100%	GJW115A1138	100%
Plate13	KL10AV6633	KL10AV6633	100%	33	20%
Plate14	HPSX4000	HPSX4000	100%	HPSX4000	100%
Plate15	MH21V9926	MH21V9926	100%	H21V9926	89%
Plate16	B505WLG	B5O5WLG	86%	B5O5WLG	86%
Plate17	DL3CAY9324	DL3CAY9324	100%	DL3CAY9324	100%
Plate18	HR26BP3543	HR26BP3543	100%	HR26BP3543	100%
Plate19	WB74X7605	W874X76O5	78%	W874X761O5	78%
Plate20	UP14CB7145	UP14CB7145	100%	UP14CB7145	100%
	Average		93,55%		82,5%

DISCUSSION

The results of this study indicate significant progress in automatic character recognition technology for license plates. Based on Table 2, the accuracy of reading original images reached 93.55% from 100%, recognizing 13 out of 20 license plate images accurately. When tested with low-resolution and blurred images with grain filters, the system achieved an accuracy of 82.5% from 100%, recognizing 9 out of 20 images accurately. These results highlight the potential of the developed technology for practical applications.

In comparison to previous research, the study's accuracy surpasses the achievements of some earlier studies. In previous research, (Etomi & Onyishi, 2021) had 100% plate localization accuracy and 90% reading. The study (Kusumadewi et al., 2019) achieved an accuracy of up to 80%. In the context of this comparison, this research demonstrates a significant development in automatic character recognition technology, providing it with broad application potential in a variety of practical situations.

The results also emphasize the importance of image quality in character recognition. Low-resolution and blurred images pose challenges for accurate detection and recognition of characters on license plates. Therefore, it is crucial to ensure higher-resolution images to enhance accuracy in character recognition.

CONCLUSION

Overall, this study succeeded in developing a vehicle license plate recognition system with fairly good reading accuracy, namely a reading accuracy of 93.55% of 100%, and recognizing 13 out of 20 license plate images accurately when tested. Even so, there are some errors in reading characters such as 0 which is read by O, D which is read 0, and 8 and 6 which are read by B. In addition, character 1 is also read as J. This error can be caused by several factors, including variations of other characters and complex license plate patterns, as well as poor image quality or uneven lighting. In addition, testing was also carried out with sample images that were given a grain filter to make them look blurry, the reading accuracy was 82.5% of 100%, with 9 out of 20 images detected accurately. this explains that low-resolution or blurry images can significantly reduce accuracy.

To overcome this, several solutions can be considered. First, more comprehensive character templates can help identify visually similar characters. Second, advanced image processing techniques such as denoising or contrast enhancement can be utilized to improve image quality before recognition. Third, the use of more adaptive character recognition techniques such as deep learning-based methods can help in dealing with more complex character variations. By implementing this solution, it is hoped that the character recognition accuracy on vehicle license plates can be significantly improved. For future research, OCR might be combined using some pre-processing processes to improve the results.

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