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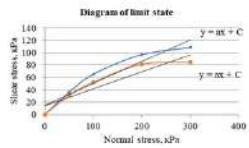

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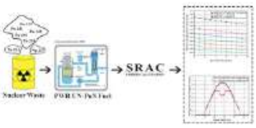

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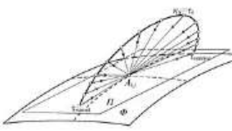

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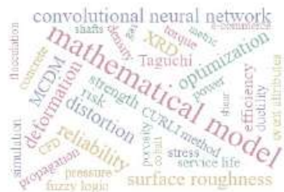

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RESEARCH OF INDONESIAN LICENSE PLATES RECOGNITION ON MOVING VEHICLES

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Abstract

The recognition of the characters in the license plate has been widely studied, but research to recognize the character of the license plate on a moving car is still rarely studied. License plate recognition on a moving car has several difficulties, for example capturing still images on moving images with non-blurred results. In addition, there are also several problems such as environmental disturbances (low lighting levels and heavy rain). In this study, a novel framework for recognizing license plate numbers is proposed that can overcome these problems. The proposed method in this study: detects moving vehicles, judges the existence of moving vehicles, captures moving vehicle images, deblurring images, locates license plates, extracts vertical edges, removes unnecessary edge lines, segments license plate locations, Indonesian license plate cutting character segmenting, character recognition. Experiments were carried out under several conditions: suitable conditions, poor lighting conditions (dawn, evening, and night), and unfavourable weather conditions (heavy rain, moderate rain, and light rain). In the experiment to test the success of the license plate number recognition, it was seen that the proposed method succeeded in recognizing 98.1 % of the total images tested. In unfavorable conditions such as poor lighting or when there are many disturbances such as rain, there is a decrease in the success rate of license plate recognition. Still, the proposed method's experimental results were higher than the method without deblurring by 1.7 %. There is still unsuccessful in recognizing license plates from the whole experiment due to a lot of noise. The noise can occur due to unfavourable environmental conditions such as heavy rain.

Keywords: license plate recognition, Indonesia license plate, moving vehicle, character recognition.

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1. Introduction

One of the identities that exist on a vehicle is the license plate number which is usually installed on the vehicle. Vehicle plates are generally placed in a position that is easy to see to be recognized. License plate recognition plays a variety of important roles in various real-life applications. The license plate is useful for traffic compliance checking, automatic toll fee debiting, parking fee debiting, and lot access control [1–3]. In particular, there are rules for license plate numbers in Indonesia that can cross certain roads. Some roads in Jakarta, Indonesia, can only be passed by vehicles with an even license number if the current date is even. On the other hand, the road can only be passed by vehicles with odd numbers if the date is odd [4, 5].

The license plate number recognition will recognize the vehicle plate number from a picture or image taken by a camera. Various cameras can produce an image with color, greyscale, or infrared cameras. Detection of vehicle objects, image processing on vehicles, image processing on license plates, and pattern recognition on license plates are techniques for recognizing vehicle number plates. However, in real-life applications, recognizing license plate numbers is not easy. There are so many variations of plate types or environmental conditions that cause challenges in license plate number recognition. The biggest challenge in real-life applications is recognizing license plate numbers on moving vehicles. In Jakarta, the capital city of Indonesia, it is necessary to recognize license plate numbers on vehicles entering certain roads, and the detection must be carried out on moving vehicles. Due to the large number of vehicles in Jakarta, both conventional vehicles and electric vehicles, arrangements are made for vehicles to pass certain roads [6].

The challenge in recognizing license plate numbers consists of three groups: variations in license plates, environmental conditions, and the background image effect. The license plate has several variations, such as the location of the different plates in an image, difference in license plate size, the font type and color of the license plate, different license plate standards, presence and dirt stuck of objects attached to the license plate [7, 8]. Environmental conditions that affect the introduction of license plate numbers include the influence of different illumination due to differences in lighting. In addition, there is a background in the image that can affect the recognition of the license plate number, such as writing patterns on cars, stickers on cars, and other writing patterns in the background. The use of license plate number recognition has many advantages, such as integrating various systems that require car identity, more accessible communication between the car identity recognition module and its application system, and easy setting of vehicle identity recognition.

In accordance with the previous explanation, the problem of recognizing license plate numbers is how to correctly recognize license plate numbers on moving vehicles. It is necessary a technique or method consisting of several modules, such as taking a still image from a moving image, detecting a license plate from an image, and recognizing a license plate number.

At this time there are several types of vehicle license plates. Vehicle license plate with a black base and white writing color for ordinary vehicles. Vehicle license plate with yellow base color and black writing color for public transportation. Vehicle license plate with red base and white writing color for government vehicles. Vehicle license plate with white base and blue lettering for diplomatic vehicles. Vehicle license plate with green base and yellow writing color for military vehicles. The restriction in this study is to recognize license plates for ordinary vehicles with a black base and white writing color.

Assuming the speed of the vehicle is not too fast, because the camera for vehicle license plate recognition is usually installed at certain intersections to check odd or even license plates.

2. Material and Methods

2. 1. Object of study

The initial step in license plate recognition is image acquisition, then followed by license plate extraction. License plates that have been extracted will be segmented and identified for their characters. The recognition steps are shown in **Fig. 1**.

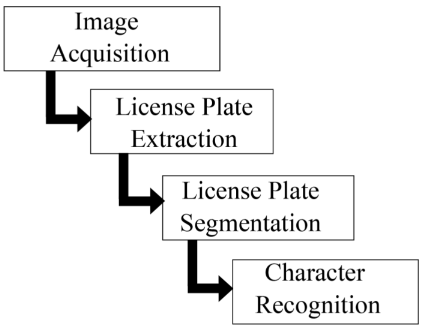

Fig. 1. Four stages of license plate number recognition

2. 2. Boundary Edge detection

Recognition of license plate numbers with boundary edge detection method uses edge detection algorithms to extract letters and numbers on license plates. The most widely used method for finding boundaries is using the Sobel filter [9]. The edge detection algorithm can recognize the number on the license plate due to differences in the character's color and the characters' background color on the license plate.

The license plate is detected by using the geometric attribute to find the lines that make up the rectangle and find the approximate area of the license plate number by matching between the vertical edges only. The vertical border on the license plate is considered the mainline for feature extraction. The horizontal line can cause errors because the line is blurred due to the car's bumper. A study to recognize Saudi Arabian license plates by Muhammad Sarfraz resulted in an accuracy of 96.2 % under various lighting conditions [10]. Another method called vertical edge detection algorithm can also be used to extract license plate numbers. The algorithm experiment shows that the recognition process is almost nine times faster than the Sobel method [11].

The advantage of using the boundary feature for license plate number recognition is that the method is straightforward, fast, and simple. The weakness of this method is that it is difficult to apply in unfavourable situations and conditions, such as interference from environmental conditions.

2. 3. Global Image Information

This method, also known as connected component analysis (CCA), uses binary image processing for license plate recognition. This method begins with measuring the area ratio to extract license plates. The research to extract license plates in low resolution Video by Hsien-Huang P. W. shows the success of license plate recognition is 96.62 % [12].

Contour detection algorithms are applied to binary images to detect connected objects. In this method, the license plate number extraction looks at connected objects with the same geometric characteristics. But this algorithm can fail if the image is of poor quality, resulting in distorted contours [13]. The advantage of the image feature method is that it is straightforward and can detect various license plate locations. But it has a shortcoming in the recognition accuracy if the license plate image is damaged.

2. 4. Texture Features

The texture feature method detects a significant change between the character color and the background color on the license plate. The detected color changes can be RGB or grayscale. The color change uses a scan line technique, resulting in the number of characters on the license plate.

Zunino studies a study to locate license plates with vector quantization. This study used the texture feature method with modified vector quantization (VQ) to identify license plate numbers [14]. The use of vector quantization can improve recognition accuracy by using more contrast and more detailed images on smaller blocks. Experimental results with various resolutions and image quality show a processing time of 200 ms with a detection accuracy of 98 %. Other modifications that can be used for the texture feature method include sliding concentric windows (SCW), Gabor filter, Discrete Fourier Transform (DFT) and Wavelet Transform (WT) [15–18].

The advantage of the texture feature method is that it can detect license plates even though the plate boundaries are not clear. But it has the disadvantage of a complex process for characters on license plates with too many edges.

2. 5. Character Features

The character feature method detects the character's location from the license plate image. The character feature algorithm searches for all characters contained in a region in a complete image [19]. The algorithm will scan the full image horizontally by looking for repeated contrast patterns. Several techniques for classifying characters include using a neural network [20].

One of the advantages of the character feature method is that the algorithm is suitable if there is a rotation of characters on the license plate. But the character method has a weakness in processing time and produces some errors if there are other characters in the image. This weakness is caused by the character feature algorithm that will process all binary objects in the complete image.

2. 6. Color Features

The shape and color of the license plate vary greatly in each country. Even within one country, sometimes there are several different license plate designs. The color feature method uses an algorithm that uses the unique nature of color differences that become the color standard for a country's license plate. It causes the implementation of the color feature algorithm to be highly dependent on the license plate object being researched. The color of each pixel in the image is categorized using hue, lightness, and saturation into multiple categories to speed up processing [21]. After the color categorization, several techniques for recognizing license plate numbers can be carried out. Recognition techniques that can be used include neural networks, genetic algorithms, and Gaussian weighted histogram intersection [22–25].

The advantage of the color feature method is that it can detect trends and change the shape of the license plate. The color feature method has shortcomings in terms of lighting. The difference in lighting color can reduce the accuracy of the recognition.

2. 7. License Plate Recognitions using Neural Networks

Neural networks can also be used for license plate recognition. There have been several studies using neural networks for license plate recognition needs. A study conducted by Hakan Caner used a method applied to a field programmable gate array (FPGA) to identify license plates [16]. The method used is raster scan video which can be applied to a system with limited memory. This system produces a portable device at a low cost. The system was successfully implemented in a controlled environment, such as controlled lighting.

In 2017, Hui Li conducted a license plate recognition study using deep neural networks [26]. License plate recognition usually consists of two steps: license plate detection and license plate character recognition. The Deep neural network method processes both steps simultaneously. This method makes the error between the two steps can be eliminated and results in a fast recognition process as well.

The license plate recognition method using a neural network has the advantage of good accuracy even though the shape of the character on the license plate has defects. However, this method has disadvantages during the training process because it takes a long time and requires many different training sets.

2. 8. Methods

As discussed in the previous section, there is a need to recognize the license plate number on a moving vehicle. One of the difficulties in recognizing license plate numbers on moving vehicles is capturing moving vehicles properly. The results of image capture on a moving image often produce a blurry image. Blurred images are challenging to recognize the license plate number, resulting in reduced recognition accuracy. In this study, a framework is proposed to be able to capture images of moving vehicles and recognize license plate numbers with high accuracy. **Fig. 2** is the framework proposed in this study, consisting of three parts: capturing images of moving cars, segmenting license plates, and the license plate recognition process.

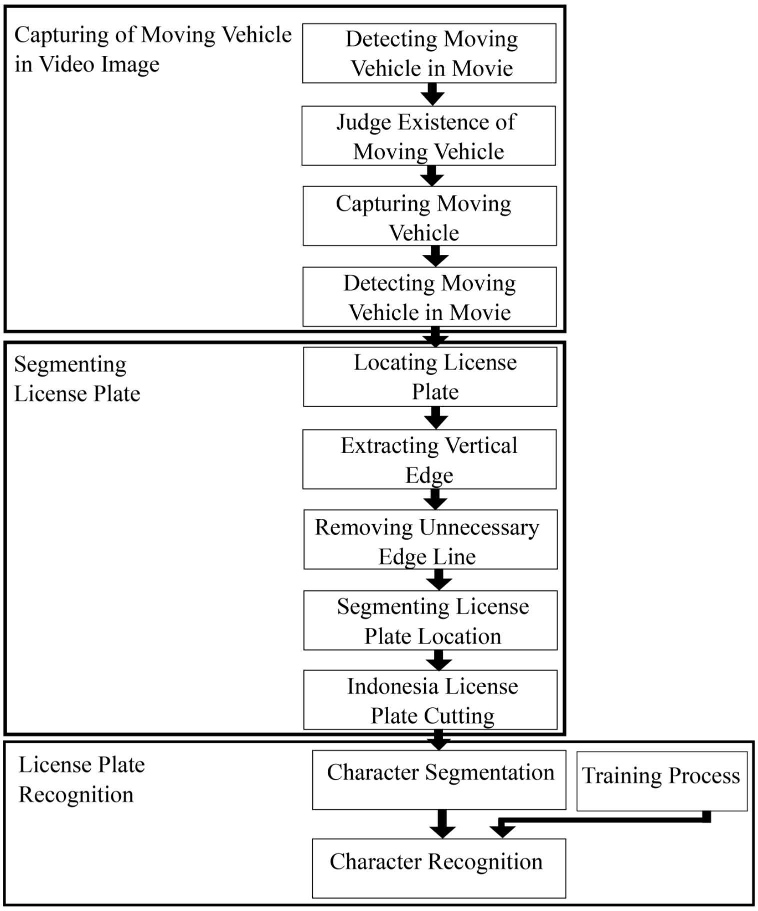

Fig. 2. License plate number recognition Framework

2. 8. 1. Detecting Moving Vehicle in Video

The three basic steps of detecting moving objects (vehicles) in the video are finding differences in two consecutive images, determining relative points on the image, and retrieving objects (vehicles) for further processing. The three steps are called segmentation processes, but they are not regular segmentation on an image but are segmentation based on successive images [27].

2. 8. 2. Judge Existence of Moving Vehicle

The process of capturing frames in a video file with properties of 30 frames per second (fps) does not have to be processed for every frame. Frame capture can be set to one frame per second to speed up the license plate recognition process. Each image in the frame is converted from an RGB image to a grayscale image (0-255). The conversion process will use the formula [28]:

$$f_i(x,y) = 0.299R_i(x,y) + 0.587G_i(x,y) + 0.114B_i(x,y), \tag{1}$$

where $f_i(x,y)$ is grayscale frame image i at point (x,y); $R_i(x,y)$ is red frame image i at point (x,y); $G_i(x,y)$ is green frame image i at point (x,y) and $B_i(x,y)$ is blue frame image i at point (x,y).

The difference between two consecutive frame images is used to see the presence of a vehicle in a video. If there is no object (vehicle) in a video, then the difference in gray level of the frames in a video will be very small. But if there is an object (vehicle), there is a large gray level difference. A threshold value is needed to determine the presence of a vehicle in a video using the formula:

$$D(x,y) = \begin{cases} 1, \text{ if } |f_1(x,y) - f_2(x,y)| > T; \\ 0, \text{ otherwise}, \end{cases} \tag{2}$$

where $f_1(x,y)$ is frame image 1 at point (x,y); $f_2(x,y)$ is frame image 2 at point (x,y); $D(x,y)$ is difference image at point (x,y) in binary and T is gray threshold. The value of the T gray threshold depends on the level of lighting on the camera and needs to be adjusted depending on the type of camera and environmental conditions. **Fig. 3** shows algorithm for detecting moving vehicles.

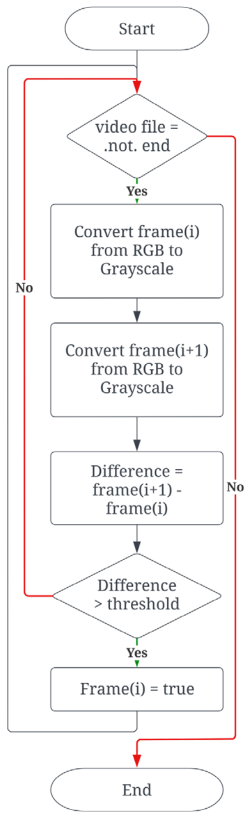

Fig. 3. Moving vehicle detection flowchart

2. 8. 3. Capturing Moving Vehicle

The process of capturing of moving vehicles uses the difference between an image without a vehicle and an image with a vehicle.

The formulas for finding *k* are:

$$S = \sum_{i=1}^{N} n_i, \tag{3}$$

$$P_i = \frac{n_i}{S}, \tag{4}$$

$$w_0 = \sum_{i=1}^{k} p_i, \tag{5}$$

$$w_1 = \sum_{i=k+1}^{N} p_i = 1 - w_0, \tag{6}$$

$$u_0 = \sum_{i=1}^{k} i \ . p_i \ / w_0 = u(k) \ / \ w_0, \tag{7}$$

$$u_1 = \sum_{i=1+1}^{N} i \ . p_i \ / w_1 = (u_1 - u(k)) \ / \ (1 - w(k), \tag{8}$$

$$\sigma_0^2 = \sum_{i=1}^{k} (i - u_0)^2 P_i \ / w_0, \tag{9}$$

$$\sigma_1^2 = \sum_{i=1+k}^{N} (i - u_1)^2 P_i \ / w_1, \tag{10}$$

$$\sigma_B^2 = w_0 (u_0 - u_y)^2 + w_1 (u_1 - u_y)^2 = w_0 w_1 (u_0 - u_1)^2, \tag{11}$$

$$\sigma_W^2 = w_0 \sigma_0^2 + w_1 \sigma_1^2, \tag{12}$$

$$\sigma_r^2 = \sum_{i=1}^{N} (i - u_y)^2 P_i, \tag{13}$$

$$k^* = \max \sigma_B^2 \ , (1 \le k \le N). \tag{14}$$

Suppose all grayscale images are n with index *i*, where *i* is 1 to *N*. Segmentation of the image by dividing the image into two parts by performing a threshold value of *k*. *S* is the accumulation of *n*, *W* is weight, and σ is variance. The threshold value of *k* is obtained by finding the maximum variance value between the two segments (σ_B).

2. 8. 4 Deblurring image

An image captured from a moving vehicle often results in a blurry image. The blurry image (*B*) is actually the result of the convolution of the good quality image with the blur kernel (*PSF*) as follows [25]:

$$B = Conv(I, K), \tag{15}$$

where *I* is the good quality image and *K* is blur kernel or *PSF*.

This process aims to reconstruct good quality images based on blurry images from the results of capturing moving vehicles. The camera that is installed to take pictures of the car is installed permanently, so the angle of the car's movement can be predicted. The angle of movement of the car produces pixel translation (u, v) in the blurry image. The translation equation is [29]:

$$\begin{bmatrix} u \\ v \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta & x \\ -\sin\theta & \cos\theta & y \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}, \quad (16)$$

where Δx is the translation vector (x-axis); Δy is the translation vector (y-axis), and θ is the rotation angle.

The deblurring image is formulated by deconvoluting the blurred image with its deconvolution value.

Deconvolution value is obtained with the formulas [25]:

$$R \otimes K = I \otimes K, \quad (17)$$

$$(B \otimes D) \otimes K = B, \quad (18)$$

$$(B \otimes (D \otimes K)) = B, \quad (19)$$

$$D \otimes K = 1 \to D(u,v) = K^{-1}(u,v), \quad (20)$$

$$I = B \otimes D, \quad (21)$$

where $\otimes$ is convolution, I is deblurring image, B is blurred image and D is deconvolution value.

2. 8. 5. Locating License Plate

Locating license plates is an essential part of the introduction of license plates. To locate the license plate: first, use a Sobel Filter to extract vertical edges, then remove noise edges in the vehicle frame, and finally convolute the image with a rectangle window [9].

2. 8. 6. Extracting vertical edge

The Sobel filter detects vertical edges because the operator is fast and straightforward. The car image is convoluted with this Sobel matrix to produce a vertical gradient image, using the formula [9]:

$$S = I \otimes \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}, \quad (22)$$

where I is deblurring image and S is vertical edge image.

2. 8. 7. Removing Unnecessary Edge Line

The results of the Sobel filter will produce many long background curves in the image in the form of vertical lines and the border on the license plate. The background in the form of vertical curves can interfere with the license plate locating.

This process will remove those vertical curves with two scanning processes and one unnecessary vertical line removal process.

The first scan is performed from the left or top start point followed by a second scan will be performed from the bottom or right endpoint.

After two scans, the two lengths are added to show the outline's original length. If the outline is very long, it will be considered an unnecessary background line and removed. If it is too short, it will be considered noise and will be deleted as well. **Fig. 4** show flowchart for removing unnecessary vertical lines and noise.

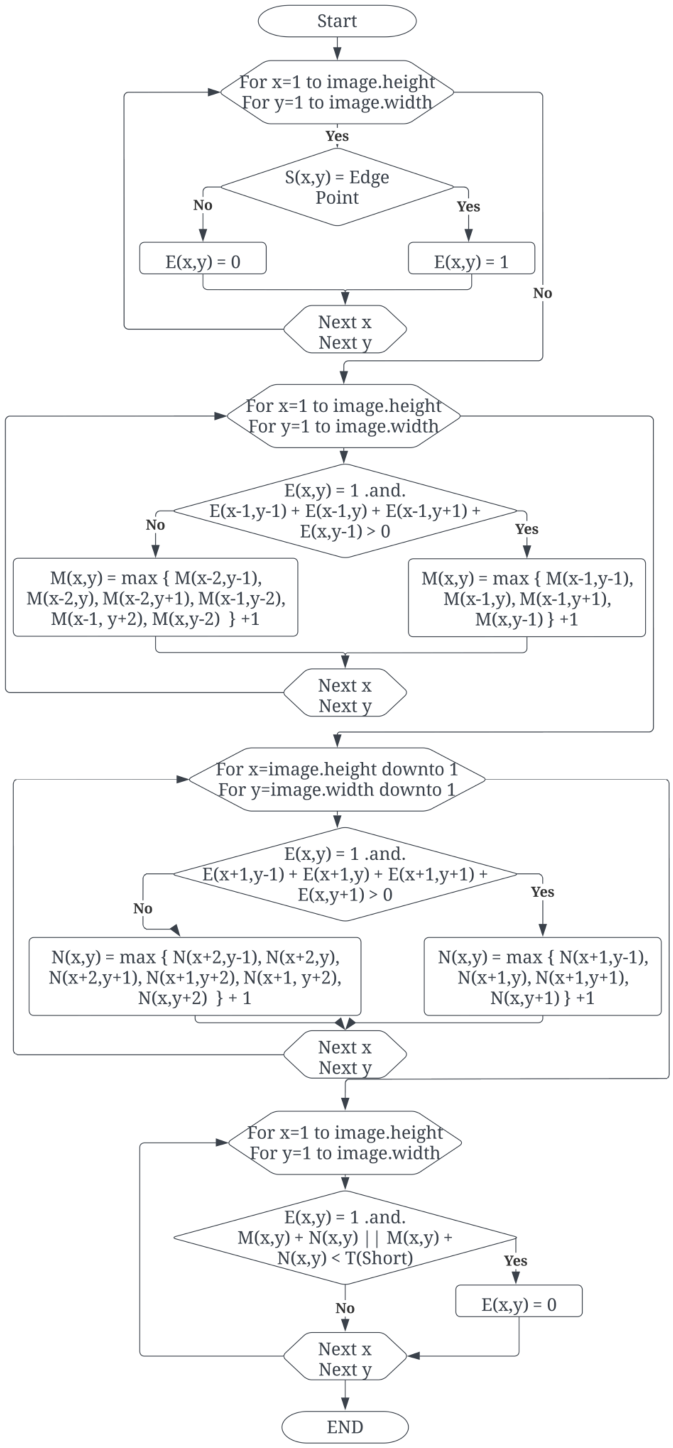

Fig. 4. Removing unnecessary edge line and noise flowchart

2. 8. 8. Segmenting License Plat Location

In the previous process, the vehicle image has been massively reduced. The image leaves only the concentrated edge lines on the part of the image that contains the license plate. This process aims to segment the car image to produce only the license plate image.

The first step is to break the image into small images. For example, a large image measuring 800×600 pixels is broken down into small images measuring 100×60 pixels. This means that there are a number of $X_{step} = 10$ and $Y_{step} = 10$. The second step is to create a matrix W measuring 20X12 with a matrix value of 1. The third step is to perform convolution as follows:

$$S' = S \otimes W. \quad (23)$$

If the value of $S'(x, y)$ is greater than T_{plate} then $S'(10x, 10y)$ is the candidate location of the license plate.

2. 8. 9. Indonesian License Plate Cutting

The shape and design of the Indonesian license plate consist of the vehicle identification number and the expiration date of the vehicle tax. A license plate consists of 70 % of the top is the vehicle identity, and the bottom 30 % is the vehicle tax expiration date, as shown in **Fig. 5**. The cutting process uses formulas:

$$S'' = S', \quad (24)$$

$$S''.\text{height} = 0.7S'.\text{image.height}, \quad (25)$$

$$S''.\text{Width} = S'.\text{width}, \quad (26)$$

where S' is the uncut image and S'' is the cut image.

Fig. 5. Indonesia license plate design

2. 8. 10. Character Segmentation

The character segmentation process aims to extract each character on the license plate. Create a rectangular model (plate bounding box). The model is moved from the position of the first character candidate to the position of the last character candidate, as shown in **Fig. 6**. In each iteration, it is checked whether the area around the square model contains characters. Indonesian license plates usually consist of 2 to 7 characters. A cropping and resizing process will be carried out if a character is found in each iteration. The resizing process aims for all characters to have the same size.

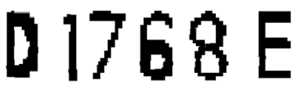

Fig. 6. Character Segmentation

2. 8. 11. Training Process

The training process uses the Principal Component Analysis (PCA) method on a collection of image databases. The database contains a set of alphanumeric character images containing various variations for each character. According to the Indonesian license plate design, the characters being trained are 0–9 and *A–Z*. In this training process, output in the form of Eigen Object and Average Object and the weight of each character contained in the database is produced. The values of these weights are stored in an array list. Principal Components Analysis (PCA) is used to reduce image dimensions to fewer features to speed up the processing time. PCA transforms the image space into a new basis or coordinate system with a more compact representation. Image bases are obtained from all the characters being trained. Principal Components Analysis will capture the total variation in the trained character set and represent this variation with fewer variables. An image represented by a few variables will be easier to handle than being represented by the raw pixels of the image.

If to define an object $u = \{u_1, u_2, u_3, ..., u_n\}$ as a vector in n dimensions. The object u can be an image and have components $u_1, u_2, u_3, ..., u_n$, where $u_1, u_2, u_3, ..., u_n$ are pixel values. With this condition, n can be interpreted as the number of pixels (= length x width) contained in the image. Then, if the object is added with other objects to become a group or a group of object $u^i = \{u_1^i, u_2^i, u_3^i, ..., u_n^i\}$, where $i = 1,..., m$ and $m \ll n$. **Fig. 7** is an example of an average value of the object.

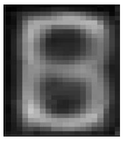

Fig. 7. Example of an average image object

The average value of the object is:

$$\bar{u} = \frac{1}{m}\sum_{k=1}^{m} u_i^k. \quad (27)$$

Covariance Matrix $c = [c_{ij}]$ is a symmetric matrix $m \times m$, where each element has an equation:

$$c_{ij} = \sum_{l=1}^{n} \left(u_l^i - \overline{u_l}\right).\left(u_l^j - \overline{u_l}\right). \quad (28)$$

Image base or Eigen Object $e^i = \{e_1^i, e_2^i, ..., e_n^i\}$, can be obtained from the formula:

$$e_l^i = \frac{1}{\sqrt{\ddot{e}_i}} \sum_{k=1}^{m} v_k^i.\left(u_k^i - \overline{u_l}\right). \quad (29)$$

2. 8. 12. Character Recognition

The character recognition process on the license plate uses the Nearest Neighbor Classifier (NNC) method. The Nearest Neighbor Classifier method calculates all the weighted values in a set of training images that have been carried out in the previous process. Nearest Neighbor Classifier calculates the weights of the training results $w_d = \left(w_d^1, w_d^2, ..., w_d^m\right)$ and the characters' weights to be recognized $w_t = \left(w_t^1, w_t^2, ..., w_t^m\right)$. The distance between the training image weight and the character to be recognized is calculated using the Euclidean Distance equation on the m-dimension using the formula:

$$d = \sqrt{\sum_{i=1}^{m} \left(w_d^i - w_t^i\right)^2}. \quad (30)$$

Based on the results of the calculations, then the smallest distance is sought between the pair of weights. The pair of weights will be searched in the database that has a value at that position. The character at the position that has the minimum distance is the result of that recognition.

3. Results and discussion

The experiment to test the framework proposed in this study is divided into several parts: License plate segmentation, character segmentation, and license plate recognition. Experiments were carried out under several conditions: suitable conditions, poor lighting conditions (dawn, evening, and night), and unfavourable weather conditions (heavy rain, moderate rain, and light rain). The indicator to assess the quality of this method is the success of the license plate recognition result. Comparison with similar studies is difficult to compare because there are not many studies on license plate recognition on moving vehicles. **Fig. 8** is an example of an experimental image at each step in the proposed framework.

This system is tested to determine the level of success in plate segmentation, character segmentation, and character recognition. **Fig. 9** shows the success rate of license plate segmentation. In good lighting conditions have succeeded in segmenting the license plate by 100 %. If the lighting is reduced in the morning and evening, there is a 10 % failure in license plate segmentation, and the success decreases even more at night with poor lighting levels. Likewise, when it rains, the success in license plate segmentation decreases. **Fig. 10** shows the success rate of character segmentation. Almost all tests successfully segmented characters except for a few exceptions when the license plate image had too much noise.

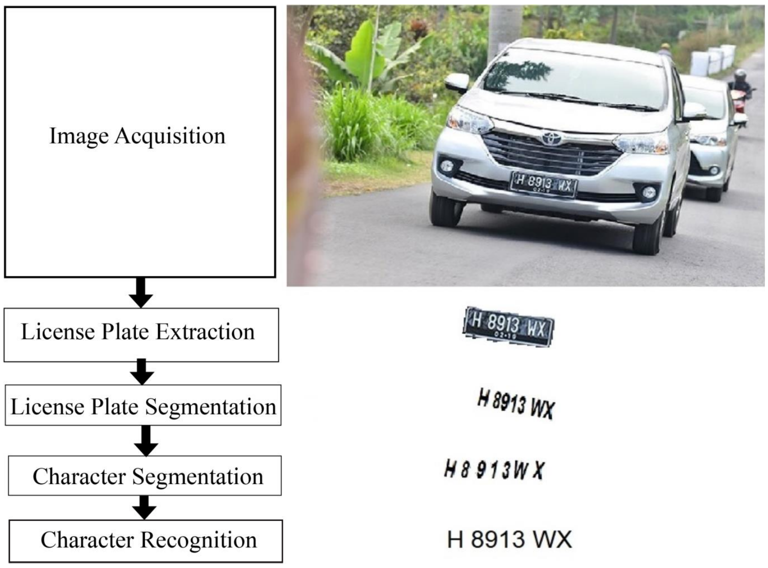

Fig. 8. Experimental Result

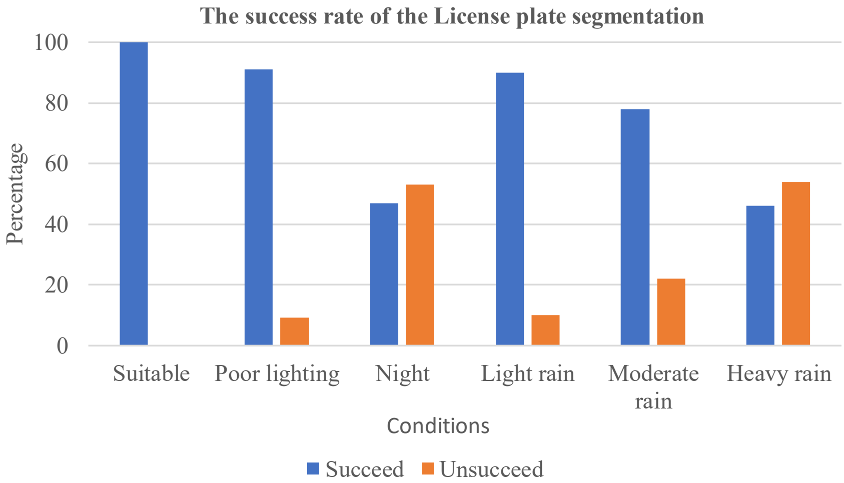

Fig. 9. The success rate of the License plate segmentation

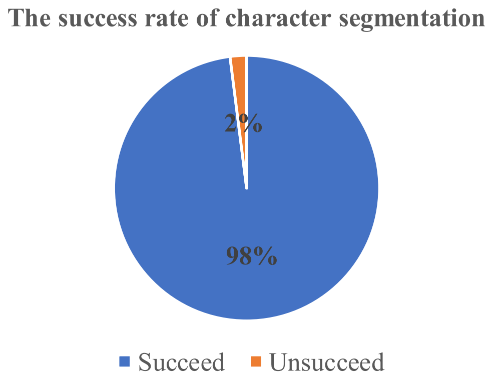

Fig. 10. The success rate of the character segmentation

Fig. 11 is the experimental result using the proposed method and the method without the deblurring method. In the experiment to test the success of the license plate number recognition, it was seen that the proposed method succeeded in recognizing 98.1 % of the total images tested. The proposed method's experimental results were higher than the method without deblurring by 1.7 %. There is still unsuccess in recognizing license plates from the whole experiment due to a lot of noise. The noise can occur due to unfavourable environmental conditions such as heavy rain.

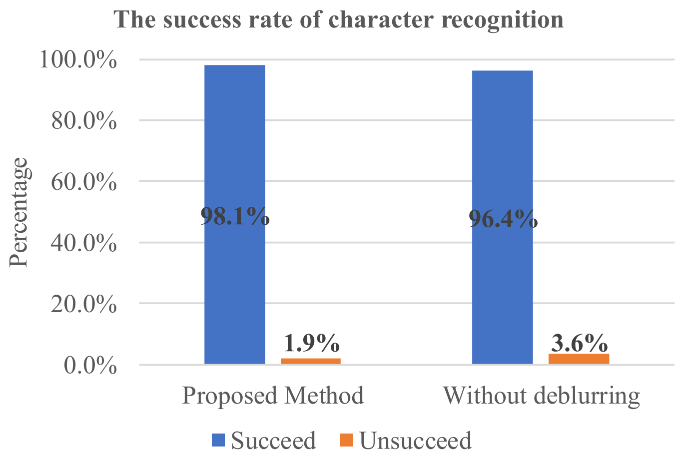

Fig. 11. The success rate of the character recognition

In actual conditions, a vehicle whose license plate is to be recognized usually has different speeds. The speed difference makes the image taken from the vehicle have different levels of clarity; some are very blurry, some are blurry, and some are not blurry. The proposed system works properly to recognize vehicle license plates even though the range of image clarity levels is very wide. This is the advantage of the system proposed in this study compared to previous studies on license plate recognition. In previous studies, the vehicle images taken had a uniform level of clarity. In previous studies, the experiment usually only used the parameter of the presence of obstacles in the vehicle image.

Based on the experimental success, this study has the advantage of recognizing the system on blurred vehicle images. This blur condition is not always caused by the speed of the vehicle but can also be due to weather such as rain or fog. In another similar study, the success was quite good, with license plate recognition success above 90 %, but the experimental results were obtained from still images.

In several experiments, several license plates were obtained which were modified by car owners such as changing the size of the license plate, adding a logo or sticker and using a shiny coating. Modifications to license plat become a limitation in the success of the license plate recognition system in this study because the proposed method does not anticipate these modifications. For further research, license plate recognition with severe environmental conditions can be further investigated. Recognition of license plates with the ability to eliminate modifications to license plates and severe environmental conditions is a new challenge in future studies. This condition is difficult to solve because the original shape of the license plate is not easy to reconstruct.

4. Conclusions

The proposed method for the introduction of license plates on moving vehicles consists of detecting moving vehicles, judging the existence of moving vehicles, capturing moving vehicle images, deblurring images, locating license plates, extracting vertical edges, removing unnecessary edge lines, segmenting license plate locations, Indonesia license plate cutting, character segmenting, character recognition. The experiment to test the framework proposed in this study is divided into several parts: License plate segmentation, character segmentation, and license plate recognition. Experiments in conditions with good lighting levels succeeded in segmenting license plates for all tests. In the morning, evening and under low lighting, the success rate decreases and when there is noise in the form of raindrops, the success rate also decreases. The proposed method successfully recognized 98.1 % of the total tested images. The experimental result of the proposed method is higher than the method without deblurring by 1.7 %. There is still unsuccess in recognizing license plates from the whole experiment due to a lot of noise. The noise can occur due to unfavourable environmental conditions such as heavy rain.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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