Designing Automatic Number Plate Recognition (ANPR) Systems Based on K-NN Machine Learning on the Raspberry Pi Embedded System

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***Abstract*—Research on vehicle number plate recognition or Automatic Number Plate Recognition (ANPR) is mostly done by researchers to produce an introduction that has high accuracy. Several methods of introduction are carried out such as introduction to edge detection and morphology, relationship analysis between objects, machine learning and deep learning. In this research a K-NN machine learning ANPR system was developed in character recognition. The method of analyzing relationships between objects is used to localize number plates. The system that was developed also added an artificial intelligence to be able to find out the fault of the number plate recognition and fix it based on the position of the character group in the number plate. The ANPR system is designed to be an Embedded system so that it can be implemented to be able to carry out the identification of two-wheeled and four-wheeled vehicle license plates. The ANPR system was also developed to be used in the parking management system. In this research the recognized number plates are limited to private number plates in Indonesia. In testing, the system is made capable of recognizing the number plates of two-wheeled vehicles and four-wheeled vehicles on vehicles that have a standard license plate according to Polri regulations, both in the font type and the number plate writing format. The results of vehicle number plate recognition reached an accuracy of 98%.**

***Index Terms*— ANPR; K-NN; Connected Component; Embedded System**

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I. INTRODUCTION

ANPR in general is an important part of a computer vision-based intelligent transportation system. The implementation of research on ALPR is used in various fields such as the development of parking management systems and can also be used to monitor traffic violations. In principle, research on ALPR is a combination of research on digital image processing, artificial intelligence and machine learning.

Many studies on ANPR in various countries. Each researcher conducts special research in certain countries and uses different methods. The method and algorithm for developing ANPR can be different because each country has a different number plate format, size, format, and type of font font. In Indonesia there are various types of vehicle plates. Special private number plates in Indonesia have a black base color with white writing. Indonesian number plates have a specific format which always starts with one or two letters. The middle section uses a number combination of one to four digits. At the end of the plate is filled with a combination of one to three letters or can also be emptied. This condition can also be used to create a more optimal algorithm for reading vehicle license plates.

II. STUDY OF LITERATURE

In this chapter, we explain the research in the field of Automatic Number Plate Recognition (ANPR) that has been done by other researchers. This chapter also explains where the researcher took part in ANPR research.

A. ANPR System Research

R. Megalingam et al., 2010, proposed a system capable of extracting plate area from vehicle images originating from India. In this study the image was taken from the back. This system consists of a digital camera and software module that extracts and recognizes the vehicle plate number. The camera takes an image from a predetermined resolution and forwards it to the software module. The software analyzes the input image, identifies the location of the plate, groups the characters in it and recognizes characters. Plate area is extracted using the concept of the relationship between components (connected component) in the image. The characters in the segmented plate using digital image labeling and character recognition are done using maching templates. The success rate in this experiment is 91% and the number of failed data is 6 images of the entire image.

R. Chen and Y. Luo, 2012, Conducted research on increasing the number plate location method based on edge detection. The study was conducted for the introduction of Chinese number plates. The first process is the RGB to Gray process. This process is used as the initial process in the input image, then the gray image is processed by stretching the image contrast to increase contrast. The stretch of gray on the contrast of the image that extends to the edge of the image becomes more so that the characteristics of the number plate scratch area are clearer and more useful in the next process

S. Du, et al., 2013, conducted a review of ANPR studies from various researchers with a variety of different methods. The focus is on number plates in Alberta, Canada. In the summary produced from the study several methods were used in each stage of ANPR processing. At the plate extraction stage, the plate is extracted based on several features such as color, boundary, or the presence of characters. At the number plate segmentation stage, characters are extracted by projecting color information by labeling the object being analyzed, or by matching the position with the template

created. The character recognition process is identified by template matching, classifiers such as neural networks and fuzzy classifiers. Problems found such as the main processing procedure, experimental database, processing time, and success rate. It is also explained that it is not appropriate to explicitly state which method shows the highest performance because there is no uniform way to evaluate each method used.

One of the things observed in the study is that there must be an increase in character recognition in several characters that have similarities such as (B-8), (O-0), (I-1), (A-4), (CG), (DO), (KX) and truncated characters.

H.F. Lahmurahma, 2013, In his research a comparison of character recognition methods using the K-NN machine learning method and Probabilistic Neural Network was compared. The result of the introduction shows that both of them can do an introduction with an accuracy of 75.38%. The process starts from the vehicle plate input data then the segmentation process and character recognition process. In the first process, the input image is only a number plate. Then the input image is converted to gray image and edge detection is done using canny detection.

Saleem, et al., 2016, proposed about vehicle plate extraction using feature extraction. Vertical edge detection algorithms are applied and eliminate unwanted edges with image normalization techniques. The number plate area was extracted by combining statistical and morphological image processing techniques. Template matching is used for optical character recognition (OCR).

First of all the obtained image is transformed into a gray scale image. Next is edge detection using the Sobel operator. Image normalization is applied to remove unwanted lines and small lumps in the image. The normalized image is then converted to a binary image. And finally filtering is done by using a Low Pass filter.

Furthermore, the image is carried out in a horizontal dilation process and then vertically with rectangular structural elements to find the area with maximum intensity to find the area of the vehicle number plate.

A.Sitompul, et al., 2016, The method used is the sliding concentric windows and connected component to detect and segment each character on the vehicle number plate. The process begins with the image resizing process to 252 x 72 to make the image has a uniform size in processing. Then it is converted into a grayscale image, then inverted and processed using the sliding concentric windows method to make the pixel on the vehicle number plate image become parts of Regions of Interest (ROI). The pixel in ROI will be given 1 and those outside the ROI area will give a value of 2. The size of the two windows used as parameters in the image of the sliding concentric windows process, is based on the aspect ratio (width: height) of Indonesian vehicle number plate characters. Characters generally have a comparison ratio of 1: 2.

M.R. Hidayah et al., 2017, Conducted research for character recognition of vehicle number plates. The study was conducted with input data in the form of vehicle license plate images without having to do vehicle plate detection beforehand. The vehicle plate image is then converted into a gray image and then the character segmentation process is performed using the otshu method to be converted into a binary image. From the next binary image, line segmentation and character segmentation are used to determine which parts of the character will be cropped one by one. The segmentation results are then carried out by the K-NN process to identify each character that has been cropped. The results of this study show that accuracy in character recognition is 93.75%, character recognition is 91.92% and the accuracy in overall vehicle number plate recognition is 82%.

A. Budianto, 2018, conducted a review of ANPR research that had been conducted to identify Indonesian license plates. The review was conducted on papers between 2010 and 2017. The ANPR process consists of four stages, namely the initial process resistance, the plate detection stage, the extraction stage and the last character recognition stage. In the study it was stated that the Morphology and Connected Component Analysis method was able to detect the location of vehicle plates in an image reaching 96.67%. In addition, the Morphology and Connected Component Analysis method is the method most often used to extract a character, where this method utilizes an object contour to extract. While to read characters, the most successful method used is the Modified Template Matching method with 99.04% results.

B. Research Mapping

Several studies have been done to get a reliable ANPR system to recognize the vehicle number plate. In TABLE I there are several comparisons of research that have been done before based on vehicle plate detection methods, character cementation and character recognition used.

TABLE I
MAPPING OF METODOLOGY

Researcher	Plate Detection	Segmentation	Recognition
R. Megalingam , 2010	Connected components	Connected components	Machine learning
R. Chen, 2012	Prewitt edge detection	-	-
H.F. Lahmurahma, 2013	-	edge detection, connected componnent	K-NN dan Probabilistic Neural Network
N. Saleem, dkk, 2016	Morphological , edge detection	Morphological, edge detection	Morphological
A.Sitompul, dkk, 2016	Sliding concentric windows and connected component	connected component labelling	Multilayer perceptron neural network and
M.R. Hidayah, dkk., 2017	Tidak ada, Data berupa plat yang siap disegmentasi	Metode Otsu	K-NN

C. *focus of Research*

In the presentation of the previous research, it was seen that research using the pre-processing stage was only by converting color images to grayscale and some using a low pass filter to smooth the image or eliminate noise. The process of producing a good pre-procesing image requires another process so that the image gets better and is ready for the next process. As in the research (B.pechiammal et al. 2017) added the thresholding process with the otshu thresholding method to convert the image into a binary image. But the weakness of the otshu method is if the image is taken with different lighting, the holding result will not be maximal. In this study proposed by using adaptive thesholding method that is able to work optimally in different lighting conditions.

In the number plate detection section, the connected component method is more widely used as in research (R. Megalingam, 2010) (A.sitompul et al., 2016) (A. Budianto, 2018) because it is easy to implement and in accordance with the criteria of number plate characters Indonesia which has special characteristics that are easy to identify. The character segmentation method uses a bounding box based on the value of the height and width of the vehicle number plate character after removal of unnecessary components.

While in the character recognition section there is a template maching method. However, with template matching, errors often occur because of the similarity of characters that are recognized besides the template maching requires considerable time to do character recognition.

Other researchers have used K-NN (H.F. Lahmurahma, 2013; M.R. Hidayah et al., 2017) in character recognition. The K-NN method is one method that is easy to implement, besides that the K-NN method has faster computing so it does not burden the system when compared to the deep learning method.

After the character recognition process, it is necessary to add an algorithm to correct character recognition errors because according to the research there are errors in the introduction of characters that have almost similar shapes (S. Du, et al., 2013). Correction of errors is done based on the position of the character whether it includes groups of letters or numbers.

In this study focused on automatic plate recognition technology research used in the parking management system by using the Connected Component Analysis method in the determination of plate location and number plate extraction. K-NN machine learning method is used in character recognition of vehicle number plates. And additional artificial intelligence algorithms to improve character recognition based on character position and distance to the next character.

III. CHARACTER RECOGNITION METHOD

This chapter discusses the research methodology carried out, including reviewing the specifications of Motorized Vehicle Number (TNKB) for private vehicles in Indonesia and vehicle number plate recognition or Automatic Number Plate Recognition (ANPR) methods. Explain the steps taken in identifying vehicle numbers using image processing.

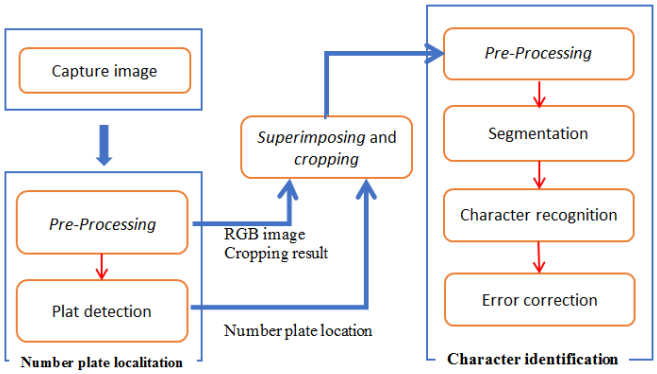

Fig. 1. Flow of the ANPR system process

A. *Image Taking*

Vehicle image retrieval is done using a webcam camera module that has a resolution of 640x480 pixels. The camera is conditioned to be able to take a vehicle image in the front area of the vehicle where it focuses around the vehicle number plate area. Image retrieval results as shown in Figure 2.

Fig. 2. The results of image capture by the camera

B. *Process of Number Plate Localization*

The process of locating the vehicle number plate consists of several stages including the initial image processing (Pre-processing) and the character detection process.

1) Pre-Processing:

The pre-processing stage consists of several stages, including the stages of cropping, grayscale, invert image, blurring and tresholding with invert. Pre-processing aims to process images taken from the camera into images that are ready for further processing. The first step to do in pre-processing is to crop the image first. Image cropping results as shown in Figure 3. Cropping is done to take a narrower area and a safe area that contains a vehicle number plate. Cropping is done to reduce the image processing area that is not needed.

Fig. 2. The results of image cropping

The second step is to convert the image into a grayscale format. The image from the RGB format is converted to HSV format. HSV consists of three color components, namely: Hue, Saturation and value. The value taken is the value of value as grayscale data because the value of value is the value that states the brightness of the image.

Fig. 4. Image Grayscale

After the image changes to the greyscale format, the next step is to do the invert process. Grayscale imagery is inverted or behind its color which is initially white and turned black, and vice versa. The purpose of the invert image process is to make the base of the image white and the main object that is the character to be analyzed becomes black. This process is done so that when separation of objects from the background results in maximum separation. The results of the inverted process as shown in figure III.8. Invert image is done by reversing the value of each image pixel with NOT notation

Fig. 5. Image Invert

The last stage in pre-processing is to do image thresholding. Thresholding is done to convert grayscale images into binary imagery. The method is done using the adactive thresholding method. Figure 6 shows the results of the coding derived from Figure 5. The threshold value on adactive thresholding is calculated using the Gaussian method where the threshold value is the sum of the surrounding values calculated by the Gaussian windows.

Fig. 6. The result of thresholding

2) Detect the Vehicle Number Plate

Pre-processing images are then processed to find all contours in the image. Displaying contours in an image is the same as doing edge detection on an image. Edge detection in an image is a process that produces edges of objects in the image. Edge is the boundary between two regions with gray-level values that are relatively different or in other words edges are places that have large intensity changes in short distances.

Fig. 7. The process results display all image contours

The next process in plate detection is eliminating contours that do not fit certain criteria. The first contour will be entered in an array value, then the contour will be sorted from the left to the right and up to the bottom.

The following are the constant values used to determine the contour criteria to be deleted.

Min_pixel_width = 5
Min_pixel_height = 25
Min_aspect_ratio = 0.25
max_aspect_ratio = 1
Min_pixel_area = 120

Fig. 8. The results of the contour elimination process

After eliminating the contour by removing the contour that has an inappropriate size, the next step is to do a contour grouping based on similarity characteristics on each contour. The characteristics of the contours used for grouping contours are as follows:

Min_diag_size = 0.2
Max_diag_size = 7
max_change_in_area = 0.6
max_change_in_width = 0.8
max_change_in_height = 0.2
Max_angle_between_chars = 3

Conditions that must be met include:

- The distance between characters must be smaller than the diagonal size of the object multiplied by the max_diag_size constant
- The angle between characters must be smaller than the max_angle_between_chars constant
- The silicih value of the object area must be smaller than the max_change_in_area constant
- The value of the difference in width of the object must be smaller than the value of max_change_in_width
- The value of the difference in height of the object must be smaller and the value of the max_change_in_height constant

After successfully grouped, each contour group is then given boundingbox as a feature that the contour group is the possibility of the vehicle number plate. The results of localization as shown in Figure 9.

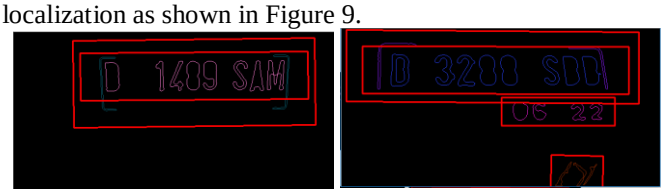

Fig. 9. Localization results of vehicle number plates

C. Superimposing dan Cropping

The next process after localizing the vehicle plate is to do the superimposing process. This process aims to combine two images to produce one image that can be processed later. Superimpose in this process is to superimpose the cropped color image in the initial pre-processing process, then overtake the boundingbox of the character localization results. The point is to move the boundingbox found in the number plate localization which was originally located in the pre-processing image, then transferred to the still-colored image as the cropping position reference on the colored image.

As shown in Figure 9 that in the picture there are some red boundingboxes which indicate a number of possible vehicle number plates detected. All possible locations of number plates that have been successfully localized are then used to superimpose with color images. Then crop the image

according to the size of each boundingbox. Gamabr III.10 shows the results of the cropping of possible number plate images.

Fig. 10. The results of cropping are possible plate images

D. Character Identification Process

Identification of number plate characters consists of several stages including the pre-processing process, character segmentation process and character recognition process using K-NN machine learning. In the number plate localization process, the resulting image consists of several possible number plate images. All images produced will be processed to identify characters and then determine which image is considered as the most appropriate plate image and display all the characters contained in the image plate as a result of identification of character recognition.

1) Pre-Processing:

The pre-processing process at the character identification stage is carried out almost the same as is done in the number plate localization process. Pre-processing is still done at this stage because the cropped image in the previous process is colored data. The pre-processing stage begins with the process of resizing the plate image as a result of the superimpose and cropping process. The image size is changed to a size of 320 pixels wide.

2) Segmentation

The process of character segmentation is the process of separating each character from the background image. Number plate images that have been successfully localized then character separation is performed. The segmentation process is not carried out directly after the localization process but must be restarted from the pre-processing process, this is because segmentation is immediately carried out after plate localization. Therefore to ensure optimal results, the process starts from the pre-processing process to prepare the number plate image.

Segmentation is done by looking at the special characteristics of each contour on the plate image. Each character on the plate has special characteristics that are almost the same as the position, length, width and aspect ratio of the character contours. This feature can be used to select the character contour to be segmented. Figure. 11 is a picture of the segmentation process.

Fig.11. Character segmentation process

3) Character Recognition

Characters that have been successfully segmented are then introduced to characters using the machine learning method K-Nearest Neighbor (K-NN). K-NN represents each data as a point in k-dimensional space. New data is tested based on the minimum distance to the nearest K neighbor that has been set. Calculation of neighbor distance is calculated using the euclidean distance equation as shown in equation III.1. Figure III.12 is a cropping character before character recognition is performed.

$$D(p,q) = \sqrt{\sum_{i=1}^{n}(pi - qi)^2} \quad (1)$$

Figure III.12. Results of cropping characters

Fig. 13. Results of ANPR system character recognition

4) Character Improvement

Character recognition does not always produce the right data. This is because when the character recognition of a vehicle plate has several similar characters, such as the characters O, 0, Q and D. Besides the similarity of data, another problem is the character shape of the vehicle plate that is not always perfect so that when processing image it produces characters that quite different from the training characters entered in the dataset. In the end character recognition becomes imperfect.

Character repairs begin by looking at the position of the character in which group on the vehicle number plate. Character groups can be seen from the index labeled and the character distance to the next character. If between characters have a distance of more than 35 pixels, the two characters are considered different groups. After knowing the position of the character group, then checking the character is in the form of numbers or letters. If found in the first group is a numerical character, it is known that there is a character recognition error and can be corrected according to the character closest to the resemblance. The results of the character improvement process are as shown in Figure 14.

Fig. 14 The results of the character improvement process.

Tests on the ANPR system were carried out on 100 previously prepared images. Of the 100 images, 98 images can be identified. Where the use of character improvement algorithms can increase the recognition that initially only 84

license plates can be upgraded to 98 number plates that can be recognized well.

IV. Implementation On Embedded System

The ANPR system created in this study was developed using an embedded system. The module used is Raspberry Pi V.2.B +. The Raspberry Pi was chosen because of the ability of the Raspbarry Pi that resembles a computer or mini PC. Raspberry Pi can be installed by an operating system and various supporting programs according to the system requirements.

The overall designed ANPR system diagram block as shown in Figure 15. The block diagram consists of a power supply as a voltage source, Raspberry Pi as an embedded system that can be installed operating system and various supporting programs, a webcam as a device that takes an image and a monitor to display the results of shooting and the results of vehicle license plate recognition.

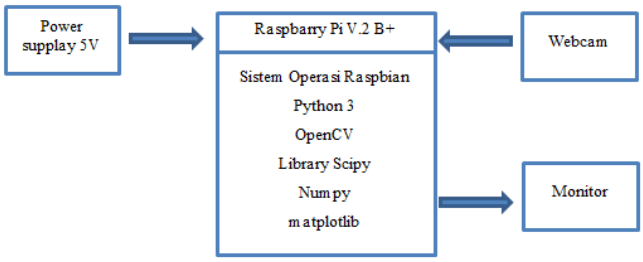

Fig. 15. Block ANPR diagram with Embedded system

A. *Raspberry Pi*

Raspberry Pi is an embedded computer created by the Raspberry Pi Foundation, a British charity that aims to educate people in computing and create easier access to computational education. The Raspberry Pi was launched in 2012 and currently Raspberry Pi has some of the latest types. The first Raspbarry Pi has a single-core 700MHz CPU and only has 256MB RAM. The latest model of the Raspberry pi has a quad-core 1.4GHz CPU with 1GB of RAM. Gamabr IV.1 is a display of a Raspbary Pi.

B. *Webcam camera*

The camera used in this study is a Logitech branded digital camera with type C310. This camera has a USB 2.0 cable as a connector that can be connected to a computer. The ability to shoot videos with a resolution of 640pixel x 480pixel. C310 webcam image as shown in Figure IV.3. This camera was chosen because it has a resolution that is not too large with good results.

C. *Installation*

Implementasi perancangan *Embedded system* dimulai dengan melakukan instalasi beberapa software pendukung. Pertama dilakukan instalasi sistem operasi Respbian pada Raspbaerry Pi. Dalam system operasi Respbian telah terinstal bahasa pemrograman python. Sehingga lebih memudahkan dalam melakukan instalasi. Setelah Rasbarry Pi terinstal system operasi maka selanjutnya adalah melakukan instalasi atau setting pada Raspbarry Pi agar port pada Raspberry Pi dapat membaca data dari modul webcam. Agar Raspbarry Pi dapat mengambil data gambar maupun video dari webcam maka perlu dilakukan instalasi sebuah modul tambahan yaitu dengan cara menginstal modul *fswebcam* dan *luvcview.*

D. *Implementation of Algorithms*

The ANPR program is designed using the python programming language. The ANPR system program was developed from a program previously developed by Chris Dahms written in the Github channel MicrocontrollerAndMore. The program was made to recognize vehicle number plates in the United States with the base color of the white plate with black writing.

Fig. 16. Software interface

In this study ANPR system was developed by adjusting several parameters of constant values and also adding program lines. Several list of programs were added to the development of the ANPR program that had previously been developed, namely adding programs to suit Indonesian license plates. In addition, a program was also added to be able to read image data from the webcam module to be implemented in real time. In the ANPR system developed an interface that can be used by the user to help see the position of the vehicle number plate when the user wants to take the vehicle image in realtime as shown in Figure IV.2. Then an artificial intelligence program is added to be able to check character recognition errors based on character groups and also the distance between characters on the number plate. Errors can occur due to the similarity of characters such as D-O, 0-O characters that are almost similar, other characters such as Z-2, I-1, B-8.

By looking at the position and distance between characters, it can be seen if there is an error in each number plate character group. In addition, each error can be corrected according to the closest possibility of the change in character and also the character table on the Indonesian number plate. For example, if O carkater is found on the first index of a number plate, it will be identified as an introduction error because there is no O character in the first letter of the Indonesian number plate. The O character will be fixed or changed to D.

The ANPR system algorithm developed was designed in a flowchat as shown in Figure. 17.

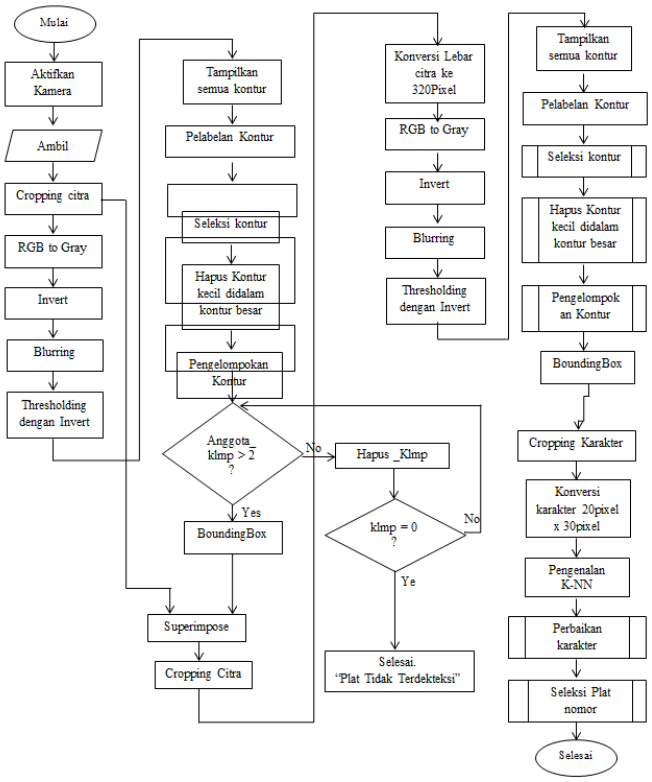

Fig. 17. ANPR system flow chart.

E. *Test Results*

Tests are carried out directly in the parking area where the vehicle is in a stationary position and the image is taken in real time by bringing embedded Raspbary PI to the parking area. Testing is done by taking 62 images of two-wheeled and four-wheeled vehicles to recognize. The results of the test show that 60 data can be recognized properly using the ANPR system that was created. Some results of number plate recognition as shown in figure 18.

Fig. 18. Number plate recognition results

V. MATH CONCLUSION

A. *Conclusion*

Based on research conducted on the design of Automatic Number Plate Recognition using embedded systems some conclusions can be drawn. First in the pre-processing image section, it can be concluded that the invert process is needed to produce a good pre-processing image so that at the final stage number plate character recognition becomes more optimal.

The method of analyzing the relationship between components used to detect vehicle number plates can produce vehicle number plate detection reaching 100% on two-wheeled and four-wheeled vehicles.

Character recognition using machine learning methods is not enough to achieve good accuracy. An algorithm is needed to correct character recognition errors based on the character group position on the vehicle number plate.

The addition of character improvement algorithms makes accuracy increase from 84% to 98%

As expected, the K-NN machine learning method on ANPR systems when implemented in embedded systems can work well and does not burden the performance of Raspbary Pi, so character recognition can be done in a relatively fast time by embedded systems.

The ANPR system that is made can recognize all characters in the number plate if the character is not damaged or cut off.

B. *Further Advice*

The development of this system can still be improved to achieve better accuracy and can be implemented directly in the parking system. Some things that can be done for the development of ANPR systems with embedded systems include optimizing the area of analysis of relationships between components in determining which part of the image is a number plate character. In this study only able to recognize up to the number of carkaters on the number plate of at least three characters. Though there is a possibility that a vehicle has only two number plate characters.

Next is an increase in algorithms in improving characters, especially characters in the final group number plate. The last group of characters consists of a collection of character letters. Where if there are letters similar to O, Q and D there could be an introduction error if the letters on the plate are not too clear. This is because the algorithm made in this study only changes the character of letters to numbers and vice versa from numbers to letters according to the position of each. So that all letters recognized in the last group of plates must be considered correct by the system.

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