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Automatic License Plate Recognition: A Review with Indonesian Case Study

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Abstract

The Automatic License Plate Recognition (ALPR) has been becoming a new trend in transportation systems automation. The extraction of the vehicle's license plate can be done without human intervention. Despite such technology has been widely adopted in developed countries, developing countries remain a far cry from implementing the sophisticated image and video recognition for some reasons. This paper discusses the challenges and possibilities of implementing Automatic License Plate Recognition within Indonesia's circumstances. Previous knowledge suggested in the literature, and state of the art of the automatic recognition technology is amassed for consideration in future research and practice.

Keywords: Automatic License Plate Recognition, OCR

1. INTRODUCTION

This article presents a comprehensive study of research on Automatic License Plate Recognition (ALPR) in Indonesia. The reviews will explain the methods used, the advantages and disadvantages of the methods used, the accuracy of the results of detection and recognition. Research review was conducted between 2010 and 2017.

Implementation of research on ALPR was used in various fields such as the development of parking systems, vehicle traffic detection system, vehicle-based toll-based toll payment system, and other areas. Research on ALPR was a combination of research on digital image processing, artificial intelligence, and machine learning.

The research on ALPR has several stages, as shown in Figure 1. ALPR Technique consists of several processes, namely 1). Capture Image, 2). Plate Detection, 3). Data Extraction and 4). Character Recognition.

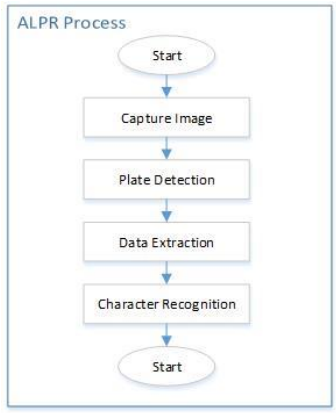

Figure 1. ALPR technique

2. METHODS

In this section, we will discuss several processes in ALPR, including:

a. Capture Image
b. Plate Detection
c. Data Extraction
d. Character Recognition

2.1. Capture Image

Before the image was processed, it must be get pre-processing to remove noise without reducing the required data. Here are some pre-processing steps, including:

1. The conversion into grayscale

Grayscale conversion changes the value of each pixel of RGB (Red Green Blue), converted into one channel value on each pixel. These processes were suggested by many researchers, among others [1-5]. The purpose of this conversion was to reduce the size of the image so that it can speed up the computation process.

2. Grayscale to binary image conversion

Some researchers suggest converting grayscale images into binary images using Thresholding method, such as those done by [2], [6-8]. The purpose of Thresholding was to separate Objects with its background.

3. Resizing the image

The purpose of this conversion was to minimize the image size to speed up the computation process. This process was done by most researchers, among others: [9-11]

2.2. Plate Detection

This section discusses methods that are widely used by researchers to detect the location of the vehicle plate. Starting with taking vehicle objects, pre-processing, filtering, and plate location detection system. The system scans the area where it will be the license plate candidate. Each candidate has tested whether it is a vehicle number plate or not. The success of the detection process will affect the subsequent process, due to plate location detection errors then the system will extract an area that is not the license plate of the vehicle.

a. Morphology and Connected Component Analysis.

Morphology is a set of operations on 2-dimensional imagery to extract components of images or objects. Morphology can be applied to a binary and grayscale representation[3]. Morphology can be used to 2 Dimensions to n Dimensions. Morphology is often used in object detection, the micro-image analysis in the field (biology, materials science, geology, and criminology), industrial inspection, character recognition, and document analysis[2]. Basic operation morphology among others: dilation, erosion, closing, and opening.

In its implementation, morphology is often followed by Connected Component Analysis or sometimes called Connected Component Labelling. Connected Component is the process of an algorithm for labelling, calculating the length, width, ratio and contour area of connected pixels forming an area or contour [4]. The labelling process makes it easy to segment, segregate with background or to separate characters in a document. Connected Component Analysis method is widely used by many researchers such as [5], [6], and [7].

Each researcher determines the size of different vehicle number plates. The size of the image pixel depends on the distance of the object with the camera. According to [8], the number plate size has a height> 50 pixels, Width> 100 pixels, Area 10,000 <area <30000, Ratio (width divided by width) between 2-5. If the contour meets the criteria, then the contour is stored in the vector of the vehicle license plate candidate. The contours that do not meet the requirements are ignored.

b. Morphology and Machine Learning

Some researchers suggest combining Morphology with Machine Learning. The reason is that image-based processing methods tend to be easier to implement, but they are not robust against environmental changes. Some researchers suggest combining morphology with machine learning methods. [8] suggests combining morphology with Ada Boost, while [9] recommends combining morphology with the Support Vector Machine.

c. Color 2D

Method of detecting plate location using 2D color method done by [12]. The color code is a 2-dimensional color code consisting of a 3 x 3 color matrix. The color code uses four colors, black, red, blue, and green, with a combination of 49 = 262,144. First, the process starts with recognizing color in color code based on

YCbCr component. The color sensor and background sensor are separated so sensors could read correctly. Each color sensor will be sampling the YCbCr component to recognize each color. Next performed the process of finding the location of the vehicle number plate using the matrix 15 x 3.

d. Horizontal-Vertical Projection

Detecting the location of the license plate using the Horizontal Method and Vertical Projection is performed by [10]. The detection process begins with preprocessing and edge detection to differentiate the edge of the digital image. The ROI (Region of Interest) were found using Vertical Projection followed by horizontal projection. Vertical projection is the sum of all magnitudes based on the y position of the image. Horizontal projection is the sum of all magnitudes based on the position of x in the image. Other studies using the Horizontal Method and Vertical Projection are [11] with the same steps as those performed by [10].

e. Viola Jones / Haar Classifier

The Haar Classifier is a method for effective object detection. This method was introduced by Paul Viola and Michael Jones in 2001. The Viola-Jones method is a machine-based learning approach. The cascade function is trained using a positive image (the image of the vehicle license plate) and the negative image (non-vehicle license plate image). After the system is trained, it used to detect objects in other images. This method has a slow training characteristic and requires a lot of training images. The advantages of the viola-jones method are very fast for the detection of an object. In a study conducted by [13], the system was trained using 1087 positive images and 2880 negative images. The Haar Classifier method is used by [14].

f. Hough Transformation

Hough transformation is one technique for feature extraction in digital image processing. The Hough Transformation [3] was originally introduced by Paul Hough in 1962. The Hough transform is used to isolate a particular shape object on the image by finding its limits. The Hough Transformation method is used by [15]. The Hough transform is applied after the segmentation process with the detection of the Sobel edge. The Hough Transformation method is also useful for straightening

g. Planar Homographies

Planar Homographies is a method to improve the position of objects to improve the accuracy of vehicle plate location detection or characters recognition. [22] Planar Homographies method can be done before or after the vehicle plate detection process. However, Planar Homographies method is more commonly used after plate detection process; the reason is that position repair is only done to the detected plate and not the entire captured image. The basic concept of Planar Homographies is to project the input pixel position to a certain position using a homograph matrix to obtain output pixel.

The following research of plate detection/localization can be seen in Table 1.

Table 1. Plate detection/localization

No.	Method	Researcher
1	Adaboost and Morphology	[9]
2	Closing Morphology and SVM	[16]
3	Color code 2D	[17]
4	Viola Jones	[13], [18]
5	Prewitt Edge Detection and Sobel Edge Detection	[19]
6	Morphology	[11], [6], [20]
7	High Pass Filter	[21]
8	Haar Cascade	[14]
9	Planar Homographies	[22]

2.3. Data Extraction

After the vehicle number plate is obtained, the next step is to extract the data from the vehicle plate. The purpose of the extraction is to get the characters in the vehicle plate. Each contour area will be scanned to get candidates of character. Each candidate of the character will be checked whether this is a character or not. In this section we will discuss methods of data extraction, among others:

a. Image convolution and Thresholding

Another method used is Image convolution and Thresholding. This technique begins with pre-processing by resizing the image and transforming it into a grayscale image. Thresholding is done to separate image with their background. The next step performs image convolution to expand the white image 1 pixel. The second thresholding is done to reduce the high image intensity. Hough transform is used to align the test image. Continue the process of character cutting on the license plate. This method is used by [16].

b. Image Centroid Zone (ICZ) and Connected Component Analysis

Zoning is one method of feature extraction, how to divide the image into several zones of the same size. Zoning method there are several algorithms for extraction method of the characteristic of zoning, such as extraction method of distance metric image centroid and zone (ICZ), extraction method of zone centroid and zone (ZCZ) and ICZ + ZCZ combination extraction methods. The study was conducted [17] using the ICZ method. The approach used in this research is the ICZ method with the following steps:

1. Calculate the centroid of the input image
2. Divide the input image into the same zone n
3. Calculate the distance between the image centroid with each pixel inside zone
4. Repeat step 3 for each pixel in the zone
5. Calculate the average distance between the points
6. Repeat the steps for the entire zone

7. The result is n features to be used in classification and introduction.

c. Morphology and Connected Component Analysis

Most of the morphology method is followed by the Connected Component Analysis method. There are various morphology methods used, among others Open-Close morphology used by [23], next researcher [24] using morphology opening to detect vehicle plate location. [25] and [26] use the method of erosion and opening, while [5] use Closing method followed by an Opening method. Also, there are several other researchers such as [27], [6], [19] and [11] using morphologies methods.

A plate can consist of 3 - 9 characters. Each Researcher has different sizes depending on the distance of the camera, such as [6] suggesting the candidate of the character has a size of 21x15 pixels. While [8] suggested a ratio of length and width ≤ 1 and had an outer area between 600 and 8000 pixels. If a contour has a wide area, it is considered as a character of the police number. While the contours that do not meet the requirements will be ignored. The following research of character extraction can be seen in Table 2.

Table 2. Character extraction

No.	Method	Researcher
1	Connected Component Analysis	[9] , [26], [11], [6] , [20], [21]
2	Open-Close Morphology	[12]
3	Image convolution and Thresholding	[17]
4	Image centroid and zone (ICZ)	[10]
5	Morphology	[13], [18], [23]
6	Haar Wavelet	[7]
7	Contour extraction	[28]
8	Principal Component Analisis (PCA)	[24]
9	Directional Feature Extraction	[25]
10	Peak Signal to Noise Ratio	[27]
11	Canny Edge Detection	[29]

d. Peak Signal to Noise Ratio and Connected Component Analysis

The method used in this study using Connected Component Analysis by applying the method of Peak Signal to Noise Ratio after pre-processing. The Peak Signal to Noise Ratio method is used to find the difference or error between the original image and the image that the screening process has performed. This method is used by [19] and [20]. Images are filtered and measured using *Mean Squared Error* (MSE) and PSNR. The smaller the value of MSE in an image then the image has better quality. While PSNR (*Peak Signal to Noise Ratio*) is a parameter used to determine the quality of image filtering results. From the research results if the value of MSE and PSNR will result in good character recognition.

e. Principal Component Analysis (PCA)
The PCA method used by [28] to extract characteristics in character segmentation. The PCA method is suitable for character recognition cases with the same font type, such as car number plates. The PCA method can be used to reduce the dimensions of data without significantly reducing the characteristics of the data.

2.4. Character Recognition
In this section will explain some machine learning methods in the introduction of the vehicle number plate characters. Characters that have been obtained at the extraction stage will be recognized using machine learning. The system will be trained using a data sheet containing the training image. The number and variety of training imagery used will determine the success and accuracy of the system. Then the system is tested with real data. There are machine learning methods that are widely used, among others:

a. K- Nearest Neighbor (KNN)
KNN is a simple classification algorithm, taking into account the distance from the input data to the training data, then deciding the grouping of input data. While the drawback of the KNN method is the computational cost or distance calculation of each unknown vector with all the distance learning present. The KNN algorithm is sensitive to noise and improper input since the KNN method has no weight or weight for each attribute. The KNN method used by many researchers is [12], [17], [11] and [29]. Accuracy with the best KNN method resulted from research [29] which reached 90%.

b. Template Matching
Template Matching is a technique to find the small parts of the image of an image closest to the template that will be used as a reference. The matching template uses the Minimum Distance Classifier approach, which calculates the Euclidian distance between unknown pattern vectors with each pattern vector instance and the smallest distance taken. This method is used by [20], [6], [22], [27]. From the result of research using template matching done by [27] yield accuracy up to 91%.

c. Neural Network Backpropagation
Neural Network (NN) Backpropagation is one of the supervised learning methods to minimize the resulting output error. In the input section is given data and in the process given the weight value by using output error to minimize the value of the error so that the desired output target is reached. The NN method is used by [12], [23], and [7]. The best result with NN backpropagation method produced by [30] with result accuracy up to 98.69%.

d. Learning Vector Quantization (LVQ)
Learning Vector Quantization (LVQ) is one type of artificial neural network to conduct learning in a supervised competitive layer. A competitive layer will automatically learn to classify input vectors. If the input vector is close to the same, then the competitive layer will place the two input vectors into the same class.

Learning Vector Quantization (LVQ) method is used by [21], and [24]. The best result with Learning Vector Quantization (LVQ) method is produced by [24] with accuracy up to 93.333%. The following research of character recognation can be seen in Table 3.

Table 3. Character recognition

No	Researcher	Method	Result
1	[14] [16] [23]	NN Backpropagation	96%
2	[12]	PNN and K- Nearest Neighbor (KNN)	81.9%
3	[11][17] [29]	K- Nearest Neighbor (KNN)	90%
4	[10]	Kohonen neural network	79,43%
5	[6] [7][13] [22] [26] [27] [31]	Template Matching	92.6%
6	[18] [19]	NN Backpropagation	97,10%
7	[21] [28] [30]	Learning Vector Quantization (LVQ)	93.33%
8	[25]	JST Self Organizing Map (SOM)	89,05%
9	[32]	Principal Component Analysis (PCA)	80%- 100%
10	[5][24][33][34][35]	Tesseract OCR	95,69%
11	[36]	NN MLP	95.69%
12	[37]	Artificial Neural Network (ANN) and Template Matching	85.87%
13	[38]	Modified Template Matching	99,04%
14	[1]	GA optimized BPNN (GABPNN)	85,97%
15	[39]	Support Vector Machine	89.77%

e. Support Vector Machine (SVM)

SVM was chosen because it has good accuracy in pattern recognition. Also, SVM can handle cases with large dimensions. SVM has advantages in a fast learning process. While SVM has the disadvantage that SVM is not suitable to be used for large-scale data. In the research [39] using the SVM method get 89.77% accuracy in the character recognition process.

f. *Tesseract OCR*

Tesseract is an open source application, originally developed at Hewlett-Packard Laboratories Bristol and Hewlett-Packard Co., Greeley Colorado between 1985 and 1994. In 1996, Tesseract supported ports on the Windows Operating system. In 1998, Tesseract was credited with C ++. Google began developing Tesseract starting year. Tesseract is an OCR engine with support for Unicode and the ability to recognize more than 100 languages. To recognize another language, Tesseract can be trained to recognize other languages. Tesseract is used by many researchers, among others [7], [33], [34], and [35]. The best results were obtained by [35] with an accuracy of 95.69%.

3. RESULT AND DISCUSSION

From the results of several studies of vehicle plate location detection, the Morphology and Connected Component Analysis methods are most widely used. Plate Localization methods are shown in Table 1. The accuracy of the best location detection results with Color 2D method obtained by [18], obtained accuracy up to 98.3%. Furthermore, [10] and [9] used the method of Morphology and Connected Component Analysis with results of 96.67%.

Data Extraction methods are shown in Table 2 above. The most characteristic method of character extraction is the Morphology and Analysis of Connected Components. This method is similar to the method for detecting the location of the vehicle plate. The difference is the contour area parameters checked.

The result of character recognition with several methods is shown in Table 3. The result of research conducted by [38] using the Modified Template Matching method yielded the best result of 99.04%.

This paper presents a comprehensive study of plate detection and recognition research in Indonesia. From the review, results concluded there are still some obstacles in the use of vehicle license recognition applications system caused by:

a. Nonstandard vehicle plate number

Nonstandard vehicle plate number used different font types, colours, and sizes. Research conducted by [40] requires that the plate and character of vehicle plate number must be standard from Indonesian Police to avoid errors. While [8] the use of variation plate will increase the failure of character recognition.

b. Disturbance from other objects

Stickers, bolts and other objects often cover characters and cause errors in character recognition[26]. While the research conducted by [19], to only contain number plates without other objects. And according to [41] bolts that cover the characters so as not to be read by the system.

c. Light Reflections

According to [12] light reflection and illumination will affect the accuracy of the system. Meanwhile, according to [13], uneven lighting caused some characters that can't be well segmented. Incorrect lighting, according to [26] may increase system failure.

d. An Improper Image Capture Camera Angle

The angle between the vehicle and the camera will affect the result of vehicle plate detection. According to [27] Taking from the right angle will reduce the noise of an image. According to research by [24] and [12], improper angles will produce an oblique image, thus requiring a hough operation to straighten it. Meanwhile, according to [18] caused a shadow around the character plate car. Each researcher

suggested a different optimum angle, such as research conducted by [32], suggesting the optimal angle of the camera with objects between -15 ° to 15 °.

e. The Distance Between The Vehicle and The Camera

The optimal range developed will be different for a system. The system will be trained to use images of various sizes and quality. The system will be able to recognize with optimum if the training image approaches the test image, as well as the distance of the object, should be close to the training image. According to [33], [42], [35] suggests readings at a distance of 50-80cm. While [32] and [34] suggest, the optimum distance is 1m. Meanwhile, according to [9] and [39] suggested the distance of the vehicle with the camera is between 3-5m.

f. Camera Resolution

Camera resolution will affect the sharpness of the results and affect the results of digital image processing. According to [43] and [14], Small resolution cameras will produce images with small resolutions making it difficult to detect features.

g. Similar Character

Some research results such as [13] experience failure due to recognizing characters, one of the reasons is the similarity of characters between A and 4, 0 points 8 and 6, 8 and 0, I and 1 and some other characters.

h. Moving Vehicle

Most studies use images that are captured offline and processed before the introduction process. The process of shooting in real conditions with moving vehicles will produce blurry images and with angles that are not straight. So it needs advanced pre-processing to improve the accuracy of the system in recognizing the characters.

4. CONCLUSION

The vehicle license plate recognition system is a positive innovation in the field of Information Technology. This system can help in improving security through automated vehicle monitoring. There are still many obstacles that appear like the number plate is not standard, the installation is not standard and some other problems. Therefore, some solutions are needed to overcome these obstacles. First, strict rules on the use of license plates of vehicle size, type, paint, character number plate and how to install it, so that no more non-standard number plates. Second, the need for research on real-time conditions, many studies conducted on silent objects, because these two conditions are very different. Third, development of infrastructure, networks and big data systems that require expensive investments. Fourth, the need for further research on the implementation of deep learning in plate recognition in Indonesia, to improve the accuracy of vehicle plate recognition.

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