Automatic vehicle identification system using number plate recognition in POLIMAS

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Abstract. The security and management of transportation system becomes an important key in controlled place such as campus area. With an increased number of vehicles, there is a need for vehicle identification mechanism that is effective, affordable and efficient. This paper presents the development of automatic vehicle identification system using NP recognition in POLIMAS. Number Plate (NP) Recognition is an image processing technology in computer vision which captures the image of the vehicle and recognizes its NP. The system is installed at the main entrance to ensure that only the authorized vehicles can enter the campus area. Once the vehicle is detected by the input sensors, a system will capture the image of vehicle plate number. An image is then extracted and investigated character segmentation by using optical character recognition. The method used for detection of a plate number is by pre-processing of the image and using a combination of Sobel Edge Detection and Laplacian Edge Detection Techniques. Bounding Box technique is used to find the NP and character recognition. The accuracy of NP recognition has an average of 87%. The system is sustainable as the camera will only be switched on when a vehicle is present.

Keywords: Vehicle Identification, Number Plate Recognition, Image Processing, Optical Character Recognition.

1. Introduction

Number Plate (NP) Recognition is a highly accurate system that performs optical character recognition (OCR) on images to read the NP on vehicles [1][2]. The system allows for real time recognition of a vehicle’s NP and commonly uses infrared lighting to allow the camera to take the picture at any time of day or night. Security at a highly restricted area such as academic institution is highly important. However, with just security guards guarding the perimeters, human error may likely to occur. In academic campus such as Politeknik Sultan Abdul Halim Mu’adzam Shah (POLIMAS), there are strict laws required to prevent intruders or robbers which may affect the safety of the students, lecturers and assets. Many challenges must be considered in order to develop an efficient automatic authorized vehicle
identification system such as the light intensity is caused by the weather. When it is sunny it may be too bright and when it rained it may be dark or distortion may occur. Accuracy may change during the night especially when raining. It may cause an error while reading the NP. Besides that, car number plates (NPs) have different formats such as the single line NPs and double line NPs. It is an issue in Malaysia that the NPs are not uniform and some are written in cursive words [3]. The position of the NP could sometimes be at the side but mostly centre.

The objective of this work is to implement an automatic vehicle identification system that will detect and capture the image of vehicle NPs. With the increase of security risk, capturing and extracting NP can help to reduce human error.

2. System Model
The vehicle identification system is separated into two features; hardware and software configurations. Hardware configuration is the combination of a prototype and single board computer (SBC). The hardware is integrated with the software. Two different approaches are carried out in this project. The first approach is connecting the software directly to the camera to ensure that simulation could work. Once it is successful, the second approach is integrating SBC with the prototype and software. Software configuration is the method used to capture the image of the NP and process it through mathematical formulae using MATLAB. Two stages of the method used in the software; (i) extraction of a NP and segmentation, and (ii) recognition of characters.

2.1. Hardware Configuration
A Raspberry Pi 2 B+ board is a main controller of the system. The system is using a camera to capture image when an infrared sensor (IR) senses the presence of a car. Detection of the car’s presence is done using an IR sensor and it will then switch on the camera. The camera will capture image of the car. Figure 1 shows the input and output through the Raspberry Pi 2 B+ board. The IR sensor and camera are the inputs to the board while the output is the extraction and recognition of NP characters. A camera installation is a crucial step as it changes due to the surrounding and location that is being installed. Many challenges such as the position of the sun shine or when it is too dark is considered.

Figure 1. Diagram of vehicle identification system.  Figure 2. Layout of the circuit diagram.

Figure 2 shows the layout of the circuit diagram. The IR sensor connected to GPIO 14 for transmitter input is used to sense the present of a car. Two LED lights are connected to GPIO 20 and 21, Green and Red LEDs are used to show if it is authorized vehicle for entry or access is being denied respectively. Web Camera Logitech c930e is an input at Universal Serial Bus (USB) port.

2.2. Software Configuration
Software configuration is used for NP detection and vehicle identification. A simulation on NPs will be carried out to identify each step of a configuration where a certain result is expected to be shown for different techniques.
2.2.1 Pre-processing of Image. Once an image has been captured, the pre-processing can begin as it is critical in order to continue to the edge detection phase. The pre-processing consists of converting from RGB to grayscale followed by contrast and intensity adjustments. Removal of RGB is done by eliminating the saturation and hue data of the image. The RGB image comprises 30% of red, 60% of green and 11% of blue. Equation (1) is used for converting RGB to grayscale [4].

\[
\text{Grayscale} = 0.2090 \times R + 0.5870 \times G + 0.1140 \times B
\]  

(1)

The intensity and contrast are adjusted to reduce noise of image. Histogram Equalization technique is used to adjust the intensity and helps to improve the image contrast when the value of intensity image is transformed. Huge amount of data detected in grayscale image. The general way of edge detection of the image is through filtering, differentiation and detection which have higher chances of detecting the image.

2.2.2 Extraction of Number Plate. Detection of NP consists of two methods; detecting rectangular images according to the size of NP in the image and by comparison if a size matches image of NP. An edge of image may have a drastic change in the shade of colour and texture which is used to identify the dimensions and objects in image.

a) Edge Detection Technique

Sobel Edge Operator is a first order differential operator in the edge extraction techniques. Sobel mask in the Sobel operator is usually used to distinguish the boundary of objects because the processing is quicker in terms of speed and the extraction gives out thick edge operation. The extraction includes straight, horizontal and diagonal directions. It has an advantage for brightness of the boundary of the character and background. This operator consists of a pair of 3*3 convolution kernels as shown in Figure 3. Gy shows the image of Gx rotated by 90°.

![Figure 3. Convolution masks for Sobel operator.](image)

Both Gx and Gy can be combined to find the magnitude of the gradient at each point (Equation (2)),

\[
|G| = \sqrt{Gx^2 + Gy^2}
\]  

(2)

The approximation magnitude is given as Equation (3),

\[
|G| = |Gx| + |Gy|
\]  

(3)

The angle of orientation of the edge giving rise to spatial gradient as shown in Equation (4),

\[
\theta = \arctan \left( \frac{Gy}{Gx} \right)
\]  

(4)

Canny edge operator performs in multi-stage process. The image is first smoothed by Gaussian convolution. Next, 2-D derivative operator used to smoothen and highlight regions of the image. The edge gradient and direction can be determined using the same equation in Sobel operator. Thirdly, non-maximum suppression is applied to remove false response. Then, double threshold to decide for potential edges is performed. Lastly, track edge by hysteresis.
The Laplacian of Gaussian (LoG), the second derivative is very responsive to noise and it plays an important role. The rapid intensity change in the Laplacian is usually used for edge detection. Gaussian smoothing filter is still applied to reduce its sensitivity to noise. The operator of 2-D function produces the scalar function (Equation (5)):

$$\Delta f(x, y) = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$$  \hspace{1cm} (5)

Zero crossing is found as edges are examined on those pixels on the image which have locally maximum gradient. The zero crossing of the second derivative selected image edges has some threshold. The 2-D LoG function centred on zero crossing with Gaussian standard deviation is using Equation (6).

$$L_{oG}(x, y) = -\frac{1}{\pi\sigma^4} \left[1 - \frac{(x^2 + y^2)/2\sigma^2}{2\sigma^2}\right] e^{(x^2 + y^2)/2\sigma^2}$$  \hspace{1cm} (6)

The Laplacian edge detector computes the second order derivative mask using only on mask unlike the Sobel operator. The mask used is 2-D convolution kernel.

b) Combination of Edge Detection Techniques

After convert the image to grayscale, the technique which is introduced will be used as a combination. An operation is processed where both are combined to create a final detection image. There are two combinations taken in this process to identify which one is more suitable for edge detector. A combination of Canny edge and Laplacian edge detector, and another would be Sobel edge and Laplacian.

2.2.3 Segmentation and Recognition of Character. Segmentation of character is the isolation of each character on the NP. This begins with the image being divided into different subparts. The technique used for character segmentation is bounding box (Figure 4). The bounding box method is the label region enclosed with rectangular boxes followed by the determination of corner coordinates, height and width. Each alphanumerical character is covered in another bounding box. After identifying each character, it is then cropped and sent for segmentation.

Figure 4. Bounding box technique.

Figure 5. OCR using eigenvector.

After segmentation of character, comes the character recognition step. The goal is by converting an image text to characters. To develop this part, OCR algorithm is used to recognize the NP. An image that was cropped is now inverted, this is done by all white pixels are inverted to black and all black pixels are inverted to white as shown in Figure 5. The NP is 25 separated, and OCR is used to compare each character individually according to the alphanumerical database. Correlation method is used to identify each character and the result is stored in a string format.

3. Analysis and Discussion

The results on each process for vehicle identification system have been recorded. Analysis of practicality has been taken into consideration while building and carrying out this project. This section is basically about the simulation carry out to process a captured photo by a camera. The captured image is then checked in the database system to prove that the car has clearance to enter the controlled area.

3.1. Detection and Capturing of Image

As far as extraction of the plate region is concern, detection and capturing are a crucial part of this process. This part is divided into the detection of car and capturing of the NP and the image undergo pre-processing which consist of converting RGB to grayscale and enhancement of the image using
histogram equalization. However, the position of the camera do co-relate with capturing of the ideal image.

3.1.1 Comparison of Position of the Camera. The comparison of the position of the camera is to identify which position is best to install the NP camera. The two options are the front and the rear of the car. If it is place in this position, the camera would be position in a gantry position. Table 1 shows the comparison and accuracy of each position.

| Table 1. Comparison of front and rear position. |
|-----------------------------------------------|
| **Position** | Front | Rear |
| **Accuracy** | 43%   | 96%  |

| Table 2. Comparison of front and rear skewed position |
|------------------------------------------------------|
| **Position** | Front and Skewed | Rear and Skewed |
| **Accuracy** | 70%      | 66%      |

Few images have been processed and analyzed. It shown that placing a camera in front will be less accurate compared to placing it behind. However, it would be a challenge to place the camera directly behind a car. It would be easier to put at the front because it can be fixed at the boom barrier. The accuracy is lower because of surrounding of the NP. Another scenario is that placing the camera by the side. The position of the camera would be either left or right and front or rear. In short, the image taken would be slightly skewed due to the placing of the camera which is at the end of the boom barrier. The image taken would be as shown in Table 2. According to a few images processed and analyzed, it is shown that both accuracies are close together. However, the reasons are quite similar to the previous scenarios which many boxy parts on the camera cause this issue. Besides that, some accuracy is caused by the environmental factor. Therefore, the angle of the camera may contribute to the accuracy of reading the NP.

3.1.2 Comparison of Environment Factor. The surrounding environment contributes to the challenges of reading the NP. Environment issues such as lighting issues and rain may cause the brightness to change. Table 3 shows the comparison of a vehicle during day and night. The accuracy of day and night comparison is similar as long as a reasonable amount of light is available. For the night situation, a bright light is present during the simulation of this experiment. The bright light is placed shone on the vehicle to ensure the sufficient amount of light is given before capturing the image. However, the light source should not be shone too direct as it will cause reflection on the NP which contributes to an accuracy of the reading NP.

| Table 3. Comparison of day and night |
|-------------------------------------|
| **Day/Night** | Day | Night |
| **Accuracy**  | 80% | 80%   |

The angle of a camera is very crucial as the placing of the camera is based tailored according to every environment of the surrounding. If the camera is pointed where sunlight is shone directly or the
light source used at night is shone directly on the car plate, the system would misread or unable to detect the character on the NP. Figures 6 and 7 show the cause and effect of reflection cause by light source and natural sunlight respectively. The effect of the character is either blurred out or it could not be recognized. For instance, Figure 6 could not be read even character beside character ‘4’ while Figure 7 the reflection was on the character ‘6’ and ‘U’ so both of the character could not be processed.

3.1.3 Grayscale Technique. Figure 8 shows the image captured as a sample for this system. Figure 9 shows the image of Figure 8 being converted into grayscale. The reasons behind these conversions are signal to noise, the difficulty of visualization and speed. Signal to noise in a colour image will not help much in detecting the edge while grayscale images can provide higher stand out on the edges. An RGB image has difficulty in visualizing because of the pixel and various types of colour which consist of multiple dimensions while a grayscale image only has two special dimensions and one brightness dimension as a 3D image. Speed is something that is considered when using it in an application such as OCR and facial recognition as shifting or resizing the image will change the segmentation. After converting the image to grayscale, histogram equalization is performed on it to enhance the contrast of the image. Figure 10 shows the image of histogram equalization on a grayscale.

3.1.4 Comparison of Grayscale and Histogram Equalization. Figure 11 shows the comparison of the grayscale image and histogram equalization image. Histogram equalization image shows a clearer contrast. Figure 12 shows the histogram image before and after histogram equalization. This method is used to increase the contrast of the overall image.
The advantage of this method is to improve the background and foreground by adjusting the brightness and the darkness in an image. Based on both histograms, the original grayscale image shows the intensity is uneven while for histogram equalization shows how the contrast value is spread out and distributed. The darker spot will be brighter while the brighter part is darkened.

3.2. Extraction of Number Plate

After the pre-processing stage comes the stage to extract the NP. To extract the NP, few methods were proposed from combination of both edge detection techniques as it would give higher accuracy [5]. Simulation for comparison between Canny edge and Sobel edge detection was carried out as well as comparison between Sobel edge and Laplacian edge detection. The results will show which technique combination is more suitable for this system.

3.2.1 Comparison of Canny Edge and Sobel Edge Detection Technique. Figure 13 represents the comparison between Canny edge and Sobel edge [6][7]. The result of Canny edge has given many challenges to providing an accurate reading as the edge detection detected more noises compared to the Sobel edge detection. As a solution, the Sobel edge detection technique is used to provide a more reliable reading. Combination of edge detection techniques is the Sobel edge detection technique and Laplacian edge technique. Both convert from histogram equalization image respectively. A combination technique is better and the edge will be more precise [8].

![Figure 13. Comparison of (a) Canny edge detection and (b) Sobel edge detection.](image)

3.2.2 Comparison of Sobel Edge and Laplacian Edge Technique. Figure 14 shows comparison between Sobel edge detection and Laplacian edge detection after histogram equalization. These techniques are used to detect the edge extraction technique [9][10]. Sobel edge uses a gradient-based method which consists of two kernels (horizontal and vertical) while the Laplacian edge uses only one kernel. Sobel calculates the first derivative of the X and Y axes separately.

The image then undergoes convolution shows strong vertical and horizontal line in the image. On the other hand, Laplacian calculates the second order derivatives in a single pass. Laplacian will be very sensitive to noise because it undergoes second order derivatives. Laplacian usually focuses on the contour of image. The Laplacian is generally used to find whether a pixel is on the dark or light side of the edge.

![Figure 14. Comparison of (a) Sobel edge detection and (b) Laplacian edge detection.](image)
3.2.3 Combination Edge Detection Technique. Figure 15 shows the combination of Sobel edge detection and Laplacian edge technique. Sobel edge provides a standout on vertical and horizontal lines while Laplacian provide a standout on curves and contours. When both are combined the result reduces the horizontal and vertical lines as well as curves which then only the bold lines will remain. Thus, this will provide a sharper image to detect the edge [11].

![Figure 15. Combination of edge detection technique.](image)

Figure 15. Combination of edge detection technique. Figure 16. Binarization.

3.2.4 Binarization. Figure 16 shows binarization of an image after the process of combination edge detection technique. Binarization is the technique used to convert a pixel image to a binary image. Figure 17(b) shows each pixel is converted into either 0 or 1. It is turning the image into a black-and-white image. Black stands for 0 while white is 1. Figure 17(a) shows the image before binarization where it is harder to determine the edge than Figure 17(b) which only shows the lines as ‘1’. The usage of this technique is to make it easier determining the lines of the image by just using binary numbers.

![Figure 17. Image (a) before and (b) after binarization.](image)

Figure 17. Image (a) before and (b) after binarization.

3.2.5 Dilation, Fill Holes and Erode. A figure 18 show the image undergo dilation process which helps to improve the line by dilating it to make it looks thicker. It dilates binary images by enlarging the boundaries of a region. This process will grow the pixels and the region becomes smaller. Next, is filling of the holes on the binary image as shown in Figure 19. The filling of holes is filling up background pixel that is not reached as well as edges. As compared to image in Figure 19, the NP can no longer be seen as that pixel has been filled up.

![Figure 18. Dilation](image)  ![Figure 19. Fill holes.](image)  ![Figure 20. Erode.](image)  ![Figure 21. Bounding box on detected NP.](image)

Figure 18. Dilation  Figure 19. Fill holes.  Figure 20. Erode.  Figure 21. Bounding box on detected NP.

Figure 20 shows the image after eroding process which is the second mathematical morphology other than dilation. This process is applied to a binary image to erode white pixels which then leaves the image with shrink pixels leaving larger holes in those areas. Figure 21 shows the image of the bounding box on the detected NP. There are two bounding boxes which require the process to choose
which the suitable one is. The process would pick the one which is usually smaller. Therefore, the NP is selected in this image. The NP with the bounding box is cropped on and the following process is character segmentation and character recognition.

3.3. Segmentation and Recognition of Character
Before Segmentation, compliment of the image is necessary in order to use bounding box technique on the image (Figure 22). Compliment of the image is like placing XOR logic where ‘0’ s turn to ‘1’ s and ‘1’ s turn to ‘0’ s. When this method is done, the bounding box of each character is performed.

Figure 23 shows the final step before using the bounding box method to segment out the character while Figure 24 shows the bounding box on segmented character. The segmented character is then being compared to the created template. Once the comparing of each character is done, each character is read and the NP data is stored. Figure 25 shows the image after the bounding box technique is used. The bounding box of character uses the smallest rectangle to surround the image as tight and close as possible. The image is then cropped and compared to the template which is provided. Last but not least, the systems read and recognize the NP as LA2715 and it is checked in the database for accessibility.

![Figure 22. Compliment of number plate.](image)

![Figure 23. Number plate before bounding box.](image)

![Figure 24. Bounding box on segmented character.](image)

![Figure 25. Bounding box cropped.](image)

3.4. Database for Access
After reading the NP it is compared with the database in Excel. Excel is link to MATLAB to check if the NP is in the system. The following Figure 26 shows the database where it stores the NP to access into POLIMAS area. After checking if the NP is in the system, the LED light will turn green which mean the car is allowed to enter and if the LED is red it means the access is denied. It has been put to trial in MATLAB to check if for access as shown in Figure 27.

![Figure 26. Database created for access.](image)

![Figure 27. System in MATLAB.](image)

4. Result
Table 4 shows the analysis of the testing results. There are 23 samples used and the success rate of detecting the NP is 95.83%. Character Segmentation is the segment of each NP on the car. There are 151 numbers of characters in total from 23 numbers of samples and 135 characters are detected from the images. The percentage of character segmented is 89.40%.
Lastly for character recognition, it is based on the total of character segmented as for character that is not segmented is not considered. About 135 characters undergo character recognition process and 118 characters are identified correctly. The percenta
g|ge of correctly recognized character is 87.41%.

5. Conclusion
The operation of vehicle identification system was analyzed in this paper. The objectives which had been proposed in this project have been achieved. The system is able to capture the image using a web camera when a car is detected. The extraction of NP has quite an accuracy using the proposed algorithm. The techniques preferred for edge detection are the combination of Sobel edge and Canny edge detection technique. Before extraction of NP, a few factors must be considered such as, position of the camera, height and distance and surrounding environment. However, they vary from one-to-one situation and require survey before installation. Lastly, segmentation and character recognition by using bounding box and optical recognition using template matching provide satisfactory and the accuracy of the system is up to the mark. The system is able to segment and recognize the character on the NP.

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