DESIGN AND DEVELOPMENT OF A LICENSE PLATE RECOGNITION SYSTEM USING CONVOLUTIONAL NEURAL NETWORK

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Tajuk Projek : An Improved Standard Malaysian License Plate Recognition using Convolutional Neural Networks

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To my beloved father and mother

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ABSTRACT

The number of vehicles on the road has increased drastically in this decade. Due to this matter, the implementation of license plate recognition system is needed that can help to control and surveillance on traffic flow. But, in previous research the license plate recognition system performed low accuracy on character recognition stage. So, this research is carried out to make improvement in recognition stage. This research is to develop a license plate recognition system that used to recognize the standard Malaysian license plate characters using Convolutional Neural Network. The license plate recognition system consist of pre-processing process that can localize license plate region in a sample and follow by segment license plate character for Convolutional Neural Network recognition. Besides that, the parameters used by four layered Convolutional Neural Network are analyzed and the best Convolutional Neural Network architecture for license plate character recognition is obtained. As a result, license plate pre-processing stage achieved 74.7% accuracy and Convolutional Neural Network recognition stage achieved 94.6% accuracy.

ABSTRAK

Kenderaan di jalan raya telah meningkat secara mendadak dalam dekad ini. Oleh itu, pelaksanaan sistem pengecaman nombor plat kenderaan amat diperlukan untuk mengawal dan pengawasan terhadap aliran trafik. Tetapi sistem pengecaman nombor plat kenderaan yang dihasilkan dalam kajian sebelum ini, ketepatan dalam peringkat pegecaman nombor plat adalah rendah. Jadi, kajian ini dijalankan untuk penambahbaikan dalam peringkat pengecaman nombor plat. Kajian ini dijalankan adalah untuk menghasilkan satu sistem pengecaman nombor plat kenderaan yang berupaya mengecam standard nombor plat kenderaan Malaysia dengan menggunakan teknik rangkaian neural konvolusi. Sistem pengecaman nombor plat kenderaan terdiri daripada proses pra-pemprosesan yang boleh menyetempatkan nombor plat dalam sampel gambar dan diikuti dengan pengecaman nombor plat dengan menggunakan teknik rangkaian neural konvolusi. Selain itu, parameter yang digunakan dalam empat lapis rangkaian neural konvolusi telah dianalisis dan model rangkaian neural konvolusi yang terbaik untuk pengecaman nombor plat lesen telah diperolehi. Akhirnya, ketepatan nombor plat pra-pemprosesan mencapai 74.7% dan ketepatan pegecaman nombor plat dengan menggunakan teknik rangkaian neural konvolusi mencapai 94.6%.

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LIST OF ABBREVIATIONS

bpp	-	bits per pixel
CNN	-	Convolutional Neural Network
GUI	-	Graphic User Interface
ITS	-	Intelligent Transport System
LPR	-	License Plate Recognition

CHAPTER 1

INTRODUCTION

1. 1 Introduction

License plate recognition (LPR) system has become significantly important when it comes to security and traffic facilities. It applies optical character recognition method on images to read the vehicle registration plates. In terms of security, LPR has been used in traffic management to detect the owner of the car who has breach the traffic laws and to find stolen vehicles. LPR system is also used for access control to enter a building. The Automatic LPR system was introduced in 1979 at the Police Scientific Development Branch in United Kingdom for security purposes.

Image processing is the main technique to be used in LPR recognition system. Therefore, developing a LPR system is challenging since the LPR image can appear to be dirty, motion blur, poor resolution, poor lighting, low contrast, etc. There are six primary algorithms for identifying a license plate. At the beginning, LPR system will use license plate localization technique to find and isolate the license plate on the input image. After that will follow by plate orientation and sizing which is responsible to compensate for the skew of the plate and to adjust the dimensions to the required size. Then, image normalization will perform to adjust the brightness and contrast of the image. The character segmentation will perform to segregate individual character from the license plate. Last step is apply optical character recognition technique to identify the individual characters. The recognition part of LPR system has almost a routine algorithm. It involves adaptive thresholding, component labeling, feature extraction and classification. Among the five major parts, the character recognition process is the most challenging part. This is because, the recognition of the characters is highly dependent on the type of algorithms applied in the first four major parts. In fact, the segmented characters can appear in various looks. Therefore, a robust character recognition method is required and CNN is identified to cope with the mentioned challenges.

CNN is well-known as a scale and rotation invariant in pattern recognition tasks. CNN accepts raw images that have been preprocessed with minimal preprocessing algorithm and train the input samples in supervised mode. It combines compression (dimensionality reduction), feature extraction and classification processes in a single architecture. Until now, CNN has been applied to various applications such as face detection [1-9], face recognition [10-14], gender recognition [15, 16], object recognition [17-19], character recognition [20-22], texture recognition [23], etc. Despite the listed advantages, CNN has limitations in terms of cost and speed. This is due to compute intensive image processing algorithm being incorporated in the design such as convolution and subsampling. The convolution process takes almost 90% of the processing time [24]. Therefore, in order to overcome the limitation, designing a small CNN size could aid in reducing the processing time. When applying CNN for LPR system, the step number (3) is not required as CNN is robust to illumination changes.

For license plate recognition using CNN, several works have been reported in [24, 25]. In [25], they implemented LeNet-5 architecture with 7 layers by inserting the whole license plate as input and reported 98.25% accuracy. This work classifies between license plate and non-license plate and not recognizing the characters. They used 2400 license plates and 4000 non-license plate dataset and divided into train and test dataset. Since [25] is more on license plate detection, the accuracy rate is incomparable with this work.

In [24], a special form of CNN called space displacement neural network (SDNN) is used to detect license plate image and the normal form of CNN is used to classify 36 characters (numbers 0-9 and letters A-Z) with a reported accuracy of 98.14%. They used 4800 training set comprising of individual plate characters that are manually segmented and labeled. The recognition architecture comprises of 4 layers with layer 1-4 uses 5, 14, 76 and 36 feature maps respectively. Levernberg Marquardt algorithm is used as the learning algorithm. SDNN incorporates segmentation process inside CNN and has the ability to deal with large image by accepting the whole word into CNN. However, the algorithm is complex since several segmentation processes are commenced and the one with the highest scores will be selected for CNN training.

This paper focuses on the character recognition part of the LPR system to improve the recognition rate. Since the network training time depends on the size of the CNN architecture, this paper discusses on the final CNN model that has the ability to produced 100% accuracy of identifying license plate characters.

1. 2 Problem statement

The number of vehicles on the road has increased drastically in this decade. According to the Malaysia Automotive Association's statistic from year 2006 to 2015, there are more than 480,000 new vehicles registered every year. This huge number of vehicles on the road caused difficulties to control the traffic flow. The vehicle inspection operation becomes a challenging task. This causes implementation of the LPR system in intelligent transportation system (ITS) becomes significant. By this implementation, LPR system can help with surveillance and control the traffic flow.

Due to this, the research of LPR system has become a popular topic by the researches. But, according to previous researches on LPR system, the system performed with low accuracy on character recognition stage. Those low accuracy character recognition techniques such as template matching and probabilistic neural network. Due to this matter, this project is proposed to overcome this problem with better character recognition technique.

1. 3 Objectives of the study

i. To develop a LPR system by using CNN method.
ii. To propose an efficient and high accuracy algorithm for LPR system that can be used practically in the future.
iii. To design a high accuracy CNN model that can recognize the license plate character efficiently.

1. 4 Significance of the study

The importance of this research is to implement a high accuracy and efficient algorithm for a LPR system. The LPR system is developed to recognize the license plate number in a static image automatically. Furthermore, CNN is implementing to the LPR system for character recognition process in order to improve the recognition rate.

1. 5 Scope

This research is to develop a LPR system. The project scopes in this research are listed in Table 1.1.

Table 1.1: Scope of this project

Project scopes	Method or specification
Tool to develop LPR system	MATLAB software
Coding involved	MATLAB and C language
Recognition method used	CNN technique
Type of license plate to be recognized	Standard Malaysian vehicle license plate only
Mode of LPR system	Offline mode which only static images for input in this system.
Resolution of the image	16 megapixels
Developed system	Software only without any hardware involve

CHAPTER 2

LITERATURE REVIEW

2. 1 Theory

2.1.1 CNN

CNN was proposed by LeCun in 1989 purposely for handwriting recognition. The CNN architecture was called LeNet-5 consisted of 7 layers. The architecture has an alternated convolution and subsampling layer twice as the feature extraction layer before connecting it to a three-layer multilayer perceptron (MLP) as the classifier. The vast number of layers has slowed down the training process since there are twice of convolution layer. In fact, subsampling layer has also contribute in slowing down the training process.

In 2012, Mamalet and Garcia [26] have formulated a method of reducing the number of layers. The convolution and subsampling layer are fused resulting in simplifying the CNN architecture. Equation (1) indicates the fused convolution/subsampling process.

$$y_{pj}^{(l)} = f\left(\sum_{i \in M_j^{(l-1)}} \sum_{(u,v) \in K^{(l)}} w_{ji\,(u,v)}^{(l)} \circ x_{pi}^{(l-1)}(c+u, r+v) + b_j^{(l)} \right) \qquad (1)$$

$c \bmod S_x = 0, r \bmod S_y = 0.$

where $K = \{(u,v) \in N^2 \mid 0 \le u < k_x ; 0 \le v < k_y\}$, ' k_x and k_y are the width and the height of the convolution kernels $w_{ji}^{(l)}$of layer*(l)* and $b_j^{(l)}$is the bias of feature map *n* in layer*(l)*, *c* and *r* refer to the current pixel, and *p* refers to the particular training sample. The set $M_j^{(l-1)}$contains the feature maps in the preceding layer*(l-1)*that are connected to feature map *n* in layer*(l)*. The notation *f* is the activation function of layer*(l)*. The variables *u* and *v* describe the horizontal and vertical step size of the convolution kernel in layer*(l)*.The final layer is a full connection following equation (3).

$$y_{pj}^{(l)} = f\left(\sum_{i=0}^{N^{(l-1)}} x_{pi}^{(l-1)} \cdot w_{ji}^{(l)} + b_j^{(l)}\right) \quad (2)$$

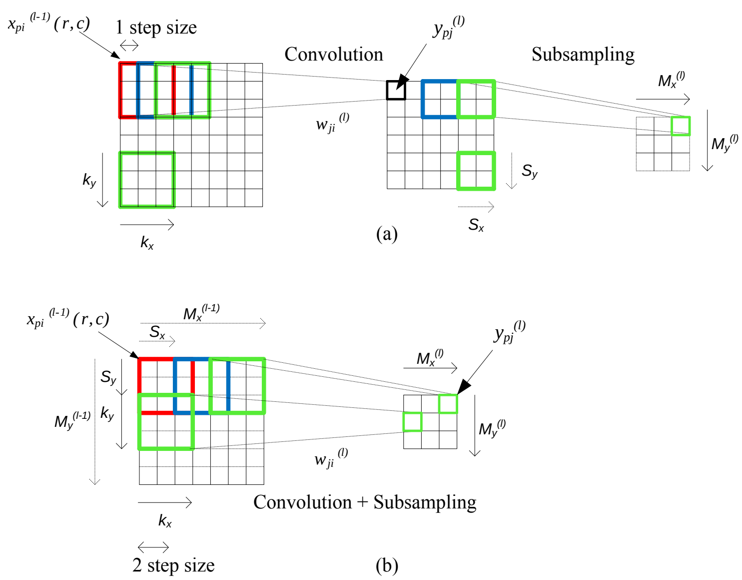

Figure 2.1: (a) convolution and subsampling LeNet-5 CNN architecture, and (b) fused convolution/subsampling in proposed CNN

where $N^{(l-1)}$is the number of neurons in the preceding layer *(l-1)*, $w_{ji}^{(l)}$is the weight for connection from neuron *i* in layer *(l-1)* to neuron *j* in layer*(l)*,$b_j^{(l)}$is the bias of neuron *j* in layer*(l)*, and *f* represents the activation function of layer*(l)*.

2.1.2 JPEG

JPEG is a format for compressing image files. The word JPEG is the acronym for Joint Photographic Expert Group. JPEG is used lossy compression for an image. It is designed to compress the color and grayscale image. For lossy compression, the file size of the image is reduced by discarding the information of the image. But this change will not detect by human eye. JPEG format images able to support 16 million colors which achieved true color standard. The JPEG format is widely used in the digital camera's photograph and other photographic image capture devices. The maximum image size of can be supported is 65,536 × 65,536 pixels.

2.1.3 Pixel

A pixel is the basic unit that used in digital image. It is a programmable color used by computer to identify and display the color on the screen. Resolution of an image is represented by using the unit of pixel. The higher the pixel used in an image, the closer the color between the image and the actual object.

The number of different colors that can be differentiated in a pixel which is depends on the number of bits per pixel (bpp). A binary image using 1 bpp to represent the image. Each pixel can either on (white) or off (black). A 1 bpp image also can be known as monochrome. The Table 2.1 shows the number of bpp and number of colors that can be represent in a pixel.

Table 2.1: The color depth that can represent in a pixel with different value of bpp

Bits per pixel (bpp)	Color depth per pixel
1	2 (monochrome)
2	4
3	8
8	256
16	65,536 (High color)
24	16,777,216 (True color)

A 16 bpp image can be known as high color graphic. The computer requires 2 bytes data space to store each pixel for the image information. One of the RGB component has 64 level intensity and other two components have 32 level intensity, so that total have 65,536 available colors using this high color graphic.

True color support 24 bpp for three RGB colors. In each pixel it requires one byte needed to be stored for each channel. The true color has total 16,777,216 color variations. It usually used to display high quality photographic images or complex graphics.

2.1.4 Malaysia standard vehicle license plate

2.1.4.1 License plate specification

Malaysian standard vehicle license plate rules derive from United Kingdom. The license plate, color, size, layout, shape and the size of the character are adhering to the guidelines provided by Road Transport Department Malaysia. The standard license plate is allowed to be used by Malaysian ordinary vehicle is license plate with white alphabets and numbers which embossed or glued on the black plate.

Figure 2.2: Malaysian standard vehicle license plate

2.1.4.2 License plate measurement

Arial bold is the standard character that can be used on the Malaysian license plate. Other than that, Road Transport Department Malaysia also standardizes the spacing of the license plate letters. The gap between the letters are 10mm. Spacing between alphabet group and number groups is 30mm. The height and width of the letters are 70mm and 40mm respectively, with a thickness of 10mm.

Figure 2.3: The standard measurement of the Malaysian vehicle license plate

2.1.5 Grayscale image

Grayscale is a technique that processes a color digital image into a gray color image. Each of the pixels in the image will carry only intensity information. Where black pixel which carry weakest intensity value and white pixel carries strongest intensity value. The brightness level of a pixel is represented as a number from 0 to 255 or in binary from 00000000 to 11111111 which it only needs 1 byte to store for each pixel.

Figure 2.4: Grayscale image