MOVING CAMERA AUTOMATIC NUMBER PLATE RECOGNITION USING NEURAL NETWORK IN ANDROID PLATFORM

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ABSTRACT

Automatic number plate recognition (ANPR) system has been widely used in many applications such as electronic payment gateway system, parking fee payment system, road monitoring system and traffic control system, as named a few. Till today, there are many methods have been proposed and developed to solve the ANPR related problems. However, most of the researches conducted were focused on fixed camera instead of moving camera. It is easy to localize and recognize the scanned car plate with fixed camera as the car plate position is almost static and can be estimated easily. But images captured using moving camera is very complex due to the background changes rapidly. Conventional ANPR system usually requires high processing power CPU and high resolutions camera, which is usually bulky and highly expensive. Recent technological advancement in smartphone industry have seen that many smartphone devices are now equipped with high end processor and high resolutions camera. Besides that, Android mobile platform is open source and equipped with many useful libraries to easily modify hardware setting programmatically such as camera. This allow the implementation of ANPR system in mobile device is possible. Based on the literature review, there are several researches have implemented ANPR system in mobile platform, but most of the researches detect license plate from static image or directly pointing the phone camera to capture license plate image. Hence, this research is conducted to provide study of the implementation of moving camera ANPR system in real time environment using Android mobile platform. This research aims to (1) design and implement image processing step for moving camera ANPR system in Android mobile platform, (2) design and implement Convolutional Neural Network (CNN) and Backpropagation Feed Forward Neural Network (BPFFNN) algorithms for moving camera ANPR system in Android platform, and (3) test and compare moving camera ANPR using CNN and BPFFNN in Android platform. The proposed localization step includes combination of Sobel edge detection method and morphological based method. Successfully detected license plate image is segmented and each character is bounded with a rectangular bounding box and cropped out. Each cropped character is feed into CNN or BPFFNN model for character recognition process. The NN model is pretrained in desktop computer or notebook and the trained NN model is then exported and implemented in the Android platform. There are five preliminary experiments have been conducted to identify the license plate search area, camera resolution of ANPR system, distance of camera with target license plate and finally, relative speed of moving camera with target license plate and vice versa. The experimental results show that the proposed technique could automatically recognize license plate in real time. Then, the performance of the proposed CNN and BPFFNN had been compared. It shows that the CNN experimental result performed better compared to BPFFNN in ANPR with moving camera approach.

ABSTRAK

MOVING CAMERA AUTOMATIC NUMBER PLATE RECOGNITION USING NEURAL NETWORK IN ANDROID PLATFORM

Sistem pengecaman nombor pendaftaran kenderaan atau lebih dikenali sebagai sistem ANPR telah diaplikasikan dalam pelbagai bidang seperti sistem gerbang pembayaran elektronik, sistem pembayaran tempat letak kenderaan, sistem pemantauan jalan raya, sistem kawalan trafik dan banyak lagi. Sehingga kini, terdapat pelbagai kaedah telah dicadangkan dan dibangunkan untuk menyelesaikan masalah-masalah dalam sistem ANPR. Walau bagaimanapun, kebanyakan kajian yang sedia ada hanya memberi tumpuan kepada kamera jenis tetap dan hanya terdapat segelintir kajian sedia ada sahaja yang menekankan terhadap kamera jenis bergerak. Proses mengesan dan membaca nombor pendaftaran kenderaan yang telah dimbas oleh sistem ANPR adalah senang untuk dilakukan dengan menggunakan kamera pengimbas yang tetap kerana posisi nombor plat kenderaan selalunya statik. Disebaliknya, imej nombor plat kenderaan yang ditangkap menggunakan kamera yang bergerak adalah lebih kompleks disebabkan latar belakang imej yang berubah dengan cepat. Sistem ANPR yang konvensional biasanya memerlukan CPU pemprosesan kuasa tinggi dan kamera resolusi yang tinggi, yang selalunya besar dan sangat mahal. Kemajuan teknologi terkini dalam industri telefon pintar membolehkan banyak peranti telefon pintar kini dilengkapi dengan CPU kuasa tinggi dan kamera resolusi tinggi. Ini membolehkan pelaksanaan langkah pemprosesan imej sistem ANPR di dalam telefon pintar. Kajian literatur menunjukkan kajian sedia ada yang melaksanakan sistem ANPR di Android tidak dijalankan dalam masa nyata. Oleh itu, tesis ini bertujuan untuk memberi kajian dalam perlaksanaan sistem ANPR Android dalam masa nyata menggunakan kaedah kamera bergerak. Kajian ini bertujuan untuk (1) mereka bentuk dan melaksanakan langkah pemprosesan imej untuk sistem pengecaman nombor plat lesen kenderaan kamera bergerak dalam telefon pintar mudah alih Android, (2) mereka bentuk dan melaksanakan rangkaian neural buatan CNN dan BPFFNN untuk kamera jenis bergerak dalam Android, (3) menguji dan membandingkan prestasi pengecaman plat kenderaan menggunakan kamera bergerak untuk CNN dan BPFFNN dalam Android. Proses mengesan plat kenderaan merangkumi kombinasi kaedah 'Sobel edge detection' dan 'morphology based method'. Plat kenderaan yang berjaya dikesan akan diasingkan dengan kaedah 'bounding box'. Setiap individual karakter akan dimasukkan dalam modal rangkaian neural buatan CNN dan BPFFNN untuk proses pengecaman karakter. Rangkaian neural buatan akan dilatih terlebih dahulu dalam komputer. Modal rangkaian neural buatan yang telah dilatih akan dieksport dan diimplementasi dalam platform Android. Lima eksperimen awal dilakukan untuk mengenal pasti kawasan carian plat lesen, resolusi kamera sistem ANPR, jarak kamera dengan plat lesen dan akhirnya, kelajuan bergerak kamera dengan plat lesen sasaran dan sebaliknya. Hasil kajian menunjukkan bahawa teknik yang dicadangkan dapat mengenali nombor pendaftaran kenderaan secara automatic dalam masa nyata. Selepas itu, prestasi CNN dan BPFFNN telah dibandingkan. Hasilnya menunjukkan bahawa hasil eksperimen CNN adalah lebih baik berbanding hasil eksperimen BPFFNN dalam persekitaran masa nyata.

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LIST OF ABBREVIATIONS

ANPR	Automatic Number Plate Recognition
ANN	Artificial Neural Networks
BPFFNN	Backpropagation Feed Forward Neural Networks
CCA	Connected Component Analysis
CNN	Convolutional Neural Networks
CPU	Central Processing Unit
CRUD	Create, Read, Update, Delete
FFNN	Feed Forward Neural Network
GPS	Global Positioning System
HSV	Hue, Saturation, Value
IDE	Integrated Development Environment
LP	License Plate
NN	Neural Networks
OCR	Optical Character Recognition
PC	Personal Computer
RGB	Red, Green, Blue
ROI	Region of Interest
SVM	Support Vector Machine

CHAPTER 1

INTRODUCTION

1.1 Introduction

Automatic number plate recognition (ANPR) also commonly known as Automatic License Plate Recognition (ALPR) or Vehicle License Plate Recognition (VNPR). ANPR is an application of image processing technology that detect, extract and recognise license plate information from an image or video frame. The extracted information can be used with or without a database system in many applications, such as real time traffic monitoring system, vehicle access control and electronic payment system which include toll payment, parking fee payment and so on (Du *et al.*, 2013). The success of ANPR system is highly dependent on the quality of the acquired image. A high quality image will give a better license plate detection and recognition success rate as compared to low quality image.

In real life application, ANPR system will have to cope with various challenges such as different types of license plate, types of font, colour of license plate and also inconsistent license plate position that increase difficulty in detecting and recognizing license plate (Hurtik & Vajgl, 2017). For example, license plate format usually varies from different nations in terms of languages, font type, font color and license plate background color. Some plates might have different color borders surrounding the license plate whereas some might have single color background license plate without border. There are some cases that the colour of the license plate background is same as the colour of the car body. This situation has further increased the complexity of license plate detection process especially when the license plate does not have a

clear invest color of border that separate it from the car body background. Variations of environmental condition such as brightness, weather and image background will also affect the license plate detection and recognition rate (Du *et al.*, 2013). Besides that, license plate also exists in different sizes. Some license plate exists in a rectangular shape and some are designed in square form. The size also varies depending on the distance of camera to license plate. When the distance of the camera with license plate is increased, the license plate is appeared smaller in the image or video frame.

Traditional car plate recognition system usually requires high resolution camera and a desktop computer or notebook to process the complex image processing algorithms. Recent technological advancement in the smartphone industry have shown many mobile devices are now equipped with high processing power CPU and high resolutions camera which meets with the requirement of a good ANPR system. Recent high-end smartphone cameras have included better camera technology. The result shows that the image quality obtained is better than some highly expensive digital camera. Since mobile device have been equipped with advance hardware, many complex applications for daily activities have been transferred from PC into mobile platform (Do et al., 2016). Mobile phone CPU chipset manufacturer company such as Qualcomm has introduced dedicated artificial intelligence processor which enables software tasks such as machine learning in imaging and photography more efficient in mobile platform (Qualcomm Snapdragon, 2018). Conventional ANPR system usually installed as fixed-point camera, where the camera is bulky and highly expensive. Besides that, Android mobile platform provides numerous infrastructures and readymade libraries that simplifies application development process, such as the ability to access the mobile device camera hardware programmatically which is one of the crucial components of ANPR system. The widely used open source computer vision library such as OpenCV provide extension and support for mobile platform implementation.

Moving camera ANPR system in mobile platform is able to provide portability and affordability to users such as law enforcement officers. This will benefit them as they can carry around the smartphone and perform traffic monitoring anywhere and anytime. Moving camera approach for ANPR system utilises real time computer vision techniques where the use of optimized algorithms in real time environment is vital to

process instant license plate detection and recognition. Hsieh et al., (2009) has proposed real time ANPR method from complex scene using the color information of braking light on the vehicle which yielded very good results. However, the aforementioned method was implemented on a computer and it consists of several major processing steps such as filtering image background with color information on braking lights and histogram equalization. These methods are not suitable for implementation in mobile device as it requires longer processing time to process color pixels on an image instead of binary image. The implementation of image processing algorithms is computationally intensive and resource exhaustive. Due to limited CPU and memory resources in mobile device, the image processing technique to be implemented need to be taken into consideration as well. In this study, image processing algorithm that is less complex and requires less processing time is preferable. For example, morphological based method and Sobel edge detector is applied for its simplicity, better performance and less processing time compared to other localization algorithm (Faradji et al., 2007). Meanwhile, the training process of NN is carried out in desktop computer instead of the mobile device in order to speed up the process.

While driving on road, the camera installed onboard might shack due to factors such as driving in high speed or uneven road surface. This will cause the camera to lose focus. Driving speed limit need to be maintained because driving in higher speed will increase the safety distance between car in front and thus increasing the distance between camera and target license plate. This will cause the difficulty of target car to get into the detection range of the system and the size of license plate will appear much smaller in the video frame. Other than that, selecting the right camera resolution is important in order to ensure not selecting low camera resolution as it will affect the license plate detection rate and selecting high camera resolution will increase the processing time.

Artificial Neural Network (ANN) is also commonly referred to as neural networks (NN) is among the popular method for solving number plate recognition problems. Backpropagation feed forward neural network (BPFFNN) and convolutional neural network (CNN) are widely used NNs in ANPR research (On et al., 2016; Yang & Li, 2017). Each of the NNs have been proven outperformed in many ANPR systems. BPFFNN (Kim & Chien, 2001) and CNN (Lee et al., 2018) have all been proven to be

well performed and demonstrated satisfactory results in researches cited. Tensorflow is a NN framework which provide supports and extensions for mobile platform implementation. The NN model for CNN and BPFFNN can be trained on desktop first instead of the mobile device. This method will save huge amount of the NN training time and it is more efficient to export the trained NN model directly to the mobile device itself. BPFFNN and CNN are chosen to be adopted in the character recognition process and the performance of the different NN architectures in mobile based real time ANPR are studied in this research.

1.2 Research Problem Background

Currently most of the car plate recognition systems that have been proposed or developed are either focused on capturing images on static vehicles to recognize the license plate or using fixed point camera to capture images and then detect and recognize the license plate (Anagnostopoulos et al., 2008; Chong et al., 2013; Lin et al., 2018). Most of the existing car plate recognition systems are still confined to gate control management or act as a traffic enforcement system where law enforcement officers use video camera that are installed on their patrol vehicles (Alegria & Girao, 2006; Felix et al., 2017). These devices usually are not portable and costly. With mobile phone, it is more cost effective compared to traditional ANPR camera and it also provides greater portability for the law enforcement officer. Besides that, mobile phone contains feature such as GPS that can be utilize to get the last seen location and time of the vehicle. With the advancement of current smartphone technologies, majority mobile devices are equipped with processors and camera features that allow the implementation of image processing technology feasible on them. Hence, this has created an initiative to carry out this research which is to localize and recognize license plate from real time video frames captured with moving camera in mobile based platform.

Most existing ANPR system requires longer processing time which is not feasible for real time processing. This may be due to higher computational complexity in the algorithm used. In order to process each sequence of video frames from the moving camera in real time, the complexity of algorithm used for ANPR system need to be reduced. Due to the limited processing power and memory resource in mobile device, ANPR algorithm in mobile device need to be optimized with suitable and

adaptive algorithm. ANPR algorithm that requires lower computational resources is much preferred in mobile platform device as it should minimize the time processing of ANPR in real time. Besides that, many existing ANPR algorithms can only detect one license plate in a frame. In real world application, a single frame might consist of more than one license plate.

The implementation and design of using a moving camera to localize and recognize license plate in video frame is much more complex and challenging if compared to static camera. This is because when the camera is moving, the background captured in the video frames change very fast and the process becomes highly complex. If road scene video is taken using moving camera, the car plate in video frame may appeared in different angle of view and size due to the distance between camera and the car. Other than that, factors such as car speed, distance of car from the camera and the quality of the camera need to be consider as it may affect the end result of recognition process. The sunlight in day time will cause reflection on the car windscreen which will be captured by the camera, this might cause some unnecessary background noise to the video frame which will further complicates the ANPR process.

1.3 Research Objectives

This research aims to achieve the following objectives:

1. To design and implement image processing step for moving camera ANPR in Android mobile platform.
2. To design and implement CNN and BPFFNN algorithms for moving camera ANPR in Android platform.
3. To test and compare moving camera ANPR for CNN and BPFFNN in Android platform in terms of number plate recognition accuracy rate.

1.4 Research Scopes

The scope of this research is as described below:

1. Only car plate with following characteristics will be used as the datasets: black color background with white color font, English letter alphabets and number digits.
2. The system is implemented in Android mobile platform only.
3. The road scene video is taken on daytime with good weather condition and sufficient amount of light and it does not take into account for night time and rainy weather.

1.5 Chapter Organization

The organization of the thesis is as follow:

Chapter 1 provides an introduction of the research. This chapter also briefly discuss topics which includes ANPR system. This chapter also includes the problem background, objectives, scopes and contribution of the research.

Chapter 2 describes the state of art of ANPR system. It first discusses about existing ANPR system that has been implemented in general. Then, it continues with the discussion of ANPR system that has been implemented in mobile based platform. Next, it discusses existing research that has implemented ANPR system with moving camera.

Chapter 3 presents the methodologies used in this research. It includes discussions of the license plate localization and segmentation methods. Then, detail of the backpropagation feed-forward neural network (BPFFNN) and convolutional neural network (CNN) is discussed. Lastly, the datasets used for NN training is discussed.

Chapter 4 describes the experimental setup for the experimental works. In this chapter, 5 set of preliminary experiment is discussed. This includes the camera resolution for ANPR system, license plate search area, distance of license plate between ANPR camera, relative speed of moving camera with license plate and relative speed of moving license plate with camera. Lastly, the experimental setup and experimental scope for BPFFNN and CNN is discussed.

Chapter 5 describes the results obtained from the experiments conducted. This includes the discussion of result obtained from real time ANPR for BPFFNN and CNN model. Lastly, the results of BPFFNN and CNN is compared in terms of ANPR accuracy rate.

Chapter 6 concludes this research with the summary of main findings obtained in this research and also brief discussion of possible future works of this research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

ANPR is a process of using digital image processing technology to detect license plate from an image or frame and recognize license plate information. It is an important research topic in computer vision, pattern recognition, and visual analysis (Wang et al., 2018). ANPR system is commonly applied in electronic payment gateway system, parking fee payment system, road monitoring system, intelligent traffic management system, etc (Rajput et al., 2015). In real life application, ANPR system have to cope with various challenges such as different type of license plate, font and color, environmental condition such as day and night time which affects the amount of light going through the camera lenses that will affect the detection and recognition of license plate.

ANPR system are generally composed of four main stages mainly known as image acquisition, license plate localization, license plate character segmentation and lastly license plate character recognition. Each of these stages are corelated with each other and plays an important role in the final ANPR accuracy rate (Wang et al., 2018). Image acquisition stage is important as obtaining high quality image will increase the license plate localization and recognition rate. Blurry or low-quality image will cause difficulty in detecting and recognizing license plate. After acquiring necessary image or video frames, license plate localization step will detect and extract license plate according to license plate features and characteristics. The result obtained from license plate localization step will directly affect the following license

plate character segmentation and character recognition stage. Character segmentation stage is where the system locates each individual character based on license plate localize area or region from the localization step. Finally, each segmented character will undergo character recognition process. Figure 2.1 shows the general ANPR flowchart.

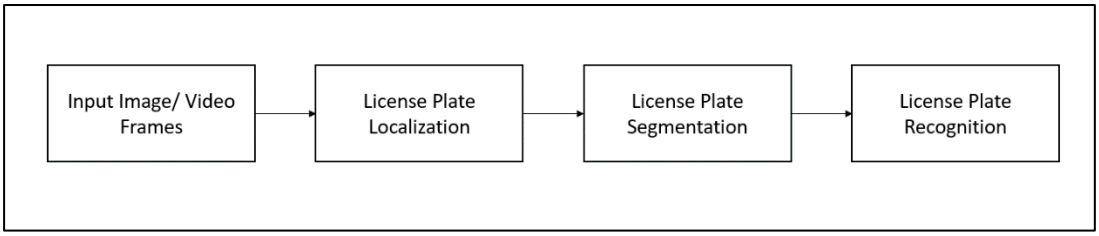

Figure 2.1: ANPR system general flowchart

2.2 Image Pre-processing

Image pre-processing step in ANPR system is the process of enhancing and restoring the quality of image before applying license plate localization algorithm. Images and video frames obtained from various conditions may contain noises, blurry or darken. Image pre-processing steps help to solve those problems by providing illumination corrections, blur and focus corrections, filtering and noise removal, edge enhancement and color space conversion (Krig, 2014). This will ultimately lead to better local and global feature detection in license plate localization step.

There are several pre-processing algorithms being applied in existing ANPR research. Grayscale conversion is commonly applied in image pre-processing algorithm. Grayscale conversion is the process of removing color information from each channel and leaving only the luminance value of an image. In number plate recognition system, grayscale conversion is applied when the license plate localization algorithms make use of the brightness information of the image or video frame. Liu & Hou (2012) converted the color image into grayscale image as it helps to identify important edges and features in the image. Color image with Red, Green and Blue (RGB) space are converted to YUV space using the following formula.

$$Y = 0.299R + 0.587G + 0.114B \tag{2.1}$$

Image or video frame captured might contain noise or dirt. Noise reduction or filtering algorithm can be applied to improve the quality of the captured image and reduce unwanted object detected in license plate localization process. Chong et al. (2013) applied a non-linear noise reduction method known as median filter to smoothen the image. Median filtering effectively removed large amount of noise in the image while preserving the important edges for further license plate detection step. Kim et al. (2017) uses Gaussian blur filter which utilize a Gaussian function for image blurring to remove noise in the image before applying edge detection algorithm. Unlike median filter, Gaussian blur filter is a linear filter and it tends to blur out edges and reduce the contrast of image.

Low contrast image or video frame can be enhanced using histogram equalization technique. Histogram equalization is a process of modifying image intensities in order to enhanced the contrast within the image (Stark, 2000). Baohua et al. (2010) implemented histogram equalization technique on image captured under strong sunlight exposure in order to enhance the intensity difference among objects and backgrounds. The result shows that by using this method, license plate can be detected accurately from overexposed image.

Binarization is one of the widely used pre-processing method to convert grayscale image to binary image. Binarization reduces the complexity of captured image or video frame as the image only consist of two color value which is 0 for black and 1 for white. One of the most commonly used image binarization method is Otsu's thresholding (Sovani, 2015). In the research, Otsu's method selects the lowest threshold value to separates between the background and object. The result shown that Otsu's method is very effective in determining and separating the foreground color which is license plate character region and the background color which is the license plate background region.

2.3 Number Plate Localization/Detection

After the pre-processing stage, the next step took place is the number plate localization step. Number plate localization is the process of detecting, locating and extracting license plate from an image or video frame. This step is crucial as the outcome from the localization step will affect the following sequential step in ANPR

system such as segmentation and character recognition step. The input in this stage is pre-processed image or video frame captured using camera. License plate can be distinguished by its feature in an image, such as edge boundary, size, color and existence of character feature (Du et al., 2013). In the following discussion, license plate localization methods used are categorized based on the features.

2.3.1 Boundary and edge based

License plates are usually in rectangular shape where the width of license plate is greater than its height. Vertical edges are one of the license plates features due to its existence of borders, characters and digits number. Babu & Nallaperumal (2008) performed license plate localization by using combination of Vertical Sobel edge detector to detect vertical edges in the input image and morphological operation for license plate extraction. After applying Sobel edge detector on the input image, the image is converted into binary image and the candidate region is extracted for morphological operation (dilation and erosion). The structuring elements are designed based on the license plate width and height and character minimum and maximum heights. The experimental result shows that the proposed license plate localization algorithm is able to achieve localization rate of over 80%. However, when the image is taken under complex background, the algorithm has struggled to locate the license plate. The robustness of the algorithm can be enhanced to detect additional features present in license plate and reducing number of non-license plate object detected. The vertical mask of Sobel operator is presented as (2.2) below.

$$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \tag{2.2}$$

Chen et al. (2009) has located license plate by detecting the rectangle region within the input image by using Hough transform method. Hough transform is a feature extraction technique that identify structural relationship of pixels in an image such as the position of an arbitrary shape. Hough transform detects the rectangular contour of the license plate based on vertical and horizontal lines. The license plate length-to-width ratio is fixed where horizontal line is about 3 times longer than

vertical line. The connected rectangle region is identified and verified as valid license plate region using the license plate color and character feature. This method is able to identified tilted or distorted license plate. The experimental result based on Chinese license plate shows that the proposed method was capable to achieve localization rate of 97% which is a very good result. However, Chinese license plate contains clear invest of border that can separate the license plate background with car body. This method is difficult in detecting license plate if the license plate was designed without border and the license plate background color is same as car body color.

Dhar et al. (2018) has presented a license plate localization method using combination of Prewitt edge detector with proposed license plate shape verification method known as distance to border vectors (DtBs). Prewitt edge detector is applied on image after noise reduction process. After detecting edges, morphological dilation is used to enhance the edges. This paper proposed a shape verification technique DtBs vectors which calculates the distances from external edges of the blob to its bounding box and it is robust for shape rotation, scaling and translation. The results show that this method is able to localize most license plate correctly and achieving 96.7% of ANPR accuracy. However, Prewitt edge detector is computationally complex compare to Sobel edge detector which makes it less preferred for mobile device implementation.

2.3.2 Character based

License plates consist of characters which can help to identify license plate region. When a string of character is presence in an image, the character region is extracted as the license plate region. Wu et al. (2007) proposed license plate localization method using connected component analysis (CCA). This method uses CCA method to label pixel into components based on pixels connectivity. The position of connected components characters is assumed to correlate with character to its left or right and thus it is considered as a candidate sequence of character components. The advantage of this method is license plate characters can be extracted from any part of the image without using the brightness information of the surroundings. This method is able to successfully extract license plate without considering the size and inclination of the license plate and the color of the vehicle body. However, this

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MOVING CAMERA AUTOMATIC NUMBER PLATE RECOGNITION USING NEURAL NETWORK IN ANDROID PLATFORM

CONNIE LIEW

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