UNIVERSITI PUTRA MALAYSIA

A FAST VERTICAL EDGE DETECTION ALGORITHM FOR CAR LICENSE PLATE DETECTION

ABBAS MOHAMMED ALI AL-GHAILI

FK 2009 28

A FAST VERTICAL EDGE DETECTION ALGORITHM FOR CAR LICENSE PLATE DETECTION

By

ABBAS MOHAMMED ALI AL-GHAILI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science

July 2009

DEDICATION

TO MY PARENTS..

TO MY SISTERS..

TO MY BROTHERS..

TO MY WIFE.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

A FAST VERTICAL EDGE DETECTION ALGORITHM FOR CAR LICENSE PLATE DETECTION

By

ABBAS MOHAMMED ALI AL-GHAILI

July 2009

Chairman: Syamsiah Mashohor, PhD

Faculty : Engineering

Recently, License Plate Detection (LPD) has been used in many applications especially in transportation systems. Many methods have been proposed in order to detect license plates, but most of them worked under restricted conditions, such as fixed illumination, stationary background, and high resolution images. LPD plays an important role in Car License Plate Recognition (CLPR) system because it affects the system's accuracy.

This thesis aims to propose a fast vertical edge detector using Vertical Edge Detection Algorithm (VEDA) and to build a Car License Plate Detection (CLPD) method.

Pre-processing step is performed in order to enhance and initialize the input image for the next steps. This step is divided into three processes: First, the color image conversion to a gray scale image. Second, an adaptive thresholding is used in order to

constitute a binarized image. Third, Unwanted Lines Elimination Algorithm (ULEA) is used in order to enhance the image. The next step is to extract the vertical edges from the 352x288 resolution image by using VEDA. This algorithm is based on the contrast between the values in the binarized image. VEDA is proposed in order to enhance the CLPD method computation time. After the vertical edges have been extracted by VEDA, a morphological operation is used to highlight the vertical details in the image. Next, candidate regions are extracted. Finally, the license plate area is detected.

This thesis shows that VEDA is faster than Sobel operator; the results reveal that VEDA is faster than Sobel by about 5-9 times, this range depends on the image resolution. The proposed CLPD method can efficiently detect the license plate area. The method shows the total time of processing one 352x288 image is 47.7 ms, and it meets the requirement of real time processing. Under the experiment datasets, which were taken from real scenes, 579 from 643 images are successfully detected. The average accuracy of car license plate detection is 90%. For more evaluation and comparison purposes, the proposed CLPD method is compared with a similar Malaysian license plate detection method, which is CAR Plate Extraction Technology (CARPET). This comparison reveled that the CLPD method is more efficient than CARPET and also has more detection rate.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi syarat keperluan ijazah Master of Science

KAEDAH PENGESANAN PLAT LESEN KERETA BERDASARKAN SEBUAH ALGORITMA BARU PENGESAN SISI MENEGAK YANG PANTAS

Oleh

ABBAS MOHAMMED ALI AL-GHAILI

Juli 2009

Pengerusi: Syamsiah Mashohor, PhD

Fakulti : Kejuruteraan

Kebelakangan ini, kaedah pengesanan plat lesen kenderaan telah digunakan dalam banyak aplikasi terutamanya dalam sistem pengangkutan. Pelbagai kaedah telah dicadangkan untuk mengesan plat lesen kenderaan, tetapi kebanyakannya berfungsi dalam keadaan yang terhad, seperti iluminasi malar, latarbelakang statik, dan imej beresolusi tinggi. Kaedah pengesanan plat lesen kenderaan memainkan peranan penting dalam sistem pengesanan plat lesen kereta kerana ia memberi kesan terhadap ketepatan sistem dan tempoh masa pemprosesan.

Tesis ini bertujuan untuk mengusulkan suatu algoritma pantas, Vertical Edge Detection Algorithm (VEDA) serta membina sebuah Pengesan Plat Lesen Kereta (CLPD) yang mengesan kawasan plat lesen kereta di dalam imej input yang diambil menggunakan *web-camera*.

Langkah pra-pemprosesan dijalankan bagi meningkatkan mutu imej dan menyediakan input imej bagi langkah yang seterusnya. Langkah ini terbahagi kepada tiga proses: Pertama, mengubah imej warna kepada imej berskala kelabu (*grayscale)*. Kedua,

kaedah pengehad ubah sendiri (*adaptive thresholding method*) digunakan untuk membina imej binari. Ketiga, Unwanted Lines Elimination Algorithm (ULEA) digunakan untuk meningkatkan kualiti imej. Langkah yang seterusnya ialah untuk mendapatkan sisi menegak daripada imej beresolusi 352x288 menggunakan VEDA. Algoritma ini berdasarkan perbezaan di antara nilai di dalam imej binari. VEDA diusulkan untuk mempercepatkan tempoh pemprosesan kaedah CLPD. Setelah imej sisi menegak dikesan dengan VEDA, operasi morfologi pula digunakan untuk mendapatkan maklumat imej sisi menegak di dalam imej. Seterusnya, maklumat bagi kawasan yang dikehendaki diambil. Akhir sekali, kawasan plat lesen kenderaan itu dapat dikesan.

Tesis ini menunjukkan bahawa VEDA adalah lebih pantas daripada operator Sobel bagi pencerapan dan pengesanan sisi menegak. Hasil kajian menunjukkan VEDA adalah 5-9 kali lebih pantas daripada Sobel, julat perbezaan antara VEDA dan Sobel adalah bergantung kepada resolusi imej. Kaedah CLPD yang telah diusulkan mampu mengesan kawasan plat lesen kereta dengan cepat dan betul. Kaedah ini menunjukkan jumlah tempoh pemprosesan sebuah imej bersaiz 352x288 ialah 47.7 ms. Di dalam dataset ujikaji yang diambil daripada senario sebenar, 579 daripada 643 imej telah berjaya dikesan. Ketepatan purata untuk mengesan plat lesen kereta ialah 90%.

Bagi tujuan penilaian dan perbandingan yang lebih mendalam, kaedah CLPD yang diusulkan telah dibandingkan dengan kaedah mengesan plat lesen kereta Malaysia yang serupa, iaitu CAR Plate Extraction Technology (CARPET). Perbandingan ini membuktikan bahawa kaedah CLPD adalah lebih cekap berbanding CARPET dan juga memberikan kadar pengesanan yang lebih tinggi.

ACKNOWLEDGEMENTS

All praise to supreme Allah (S.W.T.). The only creator, cherisher, sustainer, and able who gave me the ability to accomplish this project successfully.

I would like to thank my supervisor, Dr. Syamsiah Mashohor, for embarking with me on this project. There is nothing greater than the gift of working in a field one loves, and you allowed for this to happen. This has been an amazing learning experience. Thank you for your time, your invaluable patience to accomplish this work successfully.

My deepest gratitude goes to Dr. Alyani Ismail. Your help has been invaluable, as an advisor, guide, and family friend. Thank you for your trust, encouragement, and for creating opportunities and directing them my way. I will be in eternal debt to you.

Very special thanks to Associate Professor Dr. Abdul Rahman Ramli and the Faculty and Staff of the Department of Computer and Communication Systems. It has been an honor to work with you these past two years. You have provided me with professional and life experience, friendship and support, and made this dream true.

I am very grateful for the support of my friends in particular Dr. Ali Al-sharafi, Ahmed Muhsen, Ahmed Shawky, and Dr. Monir Abdullah.

I appreciate the support of the Fundamental Research Grant no. 5523427 by Higher Learning Education Ministry of Malaysia for providing the research grant.

I certify that a Thesis Examination Committee has met on 14 July 2009 to conduct the final examination of Abbas Mohammed Ali Al-Ghaili on his thesis entitled "A Fast Vertical Edge Detection Algorithm For Car License Plate Detection" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

Sabira Khatun, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Iqbal Saripan, PhD
Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Mohd Hamiruce Marhaban, PhD
Associate Professor
Faculty Engineering
Universiti Putra Malaysia
(Internal Examiner)

Muhammad Suzuri Hitam, PhD
Associate Professor
Faculty of Engineering
Universiti Malaysia Terengganu
(External Examiner)

BUJANG BIN KIM HUAT, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 27 August 2009

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Syamsiah Mashohor, PhD
Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Alyani Ismail, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Abdul Rahman Ramli, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

HASANAH MOHD. GHAZALI , PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 11 September 2009

DECLARATION

I hereby declare that the thesis is based on my original work except that for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions

ABBAS MOHAMMED ALI AL-GHAILI

Date: 12 August 2009

TABLE OF CONTENT

DEDICATION			**i**
ABSTRACT			**ii**
ABSTRAK			**iv**
ACKNOWLEDGEMENTS			**vi**
APPROVAL			**vii**
DECLARATION			**ix**
LIST OF TABLES			**xii**
LIST OF FIGURES			**xiii**
LIST OF ABBREVIATIONS			**xv**

CHAPTER

1	**INTRODUCTION**		**1**
	1.1	Introduction to Car License Plate Recognition System	1
	1.2	Introduction to License Plate Detection	2
	1.3	Introduction to Vehicle Tracking Systems	2
	1.4	Introduction to Vertical Edge Detection	3
	1.5	Motivation	3
	1.6	Problem statement	4
	1.7	Objectives	5
	1.8	Thesis Organization	5
2	**LITERATURE REVIEW**		**6**
	2.1	Introduction	6
	2.2	Adaptive Thresholding Techniques	6
	2.3	Edge Detection	7
		2.3.1 Sobel Theory	8
		2.3.2 Sobel-based Vertical Edge Detection	9
	2.4	License Plate Recognition	10
	2.5	Car License Plate Detection	11
		2.5.1 Texture-based License Plate Detection	12
		2.5.2 Vertical Edges-based License Plate Detection	13
		2.5.3 Color-based License Plate Detection	14
	2.6	CLPD Previous Approaches	16
	2.7	CLPD Limitations	27
	2.8	Summary	27
3	**RESEARCH METHODOLOGY**		**29**
	3.1	Introduction	29
	3.2	The CLPD Method Architecture	30
		3.2.1 Flowchart of the Proposed Method	30
		3.2.2 Hardware Configuration	31

3.3	Pre-processing Input Image	32
	3.3.1 Color Image Conversion	32
	3.3.2 Adaptive Thresholding (AT)	33
	3.3.3 Unwanted Lines Elimination Algorithm (ULEA)	36
3.4	Sobel Edge Detection Method	38
	3.4.1 Sobel vs. Canny and Prewitt	38
	3.4.2 Sobel Edge Detection Operator	39
	3.4.3 Sobel Edge Function	40
3.5	The Proposed Algorithm for Vertical Edge Detection	41
	3.5.1 Overview	41
	3.5.2 Vertical Edge Detection Algorithm (VEDA)	41
	3.5.3 VEDA output form	44
3.6	The Proposed Method for Detecting the Car License Plate	45
	3.6.1 Highlight Desired Details (HDD) Based on VEDA	45
	3.6.2 Candidate Regions Extraction (CRE)	47
	3.6.3 Plate Region Selection (PRS)	52
	3.6.4 Plate Region Detection (PRD)	58
4	**RESULTS AND DISCUSSION**	**60**
4.1	Introduction	60
4.2	Global vs. Adaptive Thresholding Comparison	60
	4.2.1 The Percentage of Image-Thresholding	61
4.3	Sobel vs. VEDA Comparison	64
	4.3.1 Sobel and VEDA Implementation	65
	4.3.2 The Processing Time	66
	4.3.3 The Accuracy	67
	4.3.4 Big-O-Notation Module-based Complexity	68
	4.3.5 Output Form	70
4.4	Evaluation of the Proposed CLPD Method	70
	4.4.1 Samples Collection	71
	4.4.2 Results Analysis and Discussion	72
4.5	CARPET vs. the Proposed CLPD Method	76
	4.5.1 The Detection Rate	77
	4.5.2 The Efficiency	77
5	**CONCLUSION**	**79**
5.1	Conclusion	79
5.2	Future Work	80
REFERENCES		**81**
LIST OF APPENDICES		**91**
BIODATA OF STUDENT		**108**
LIST OF PUBLICATIONS		**109**

LIST OF TABLES

Table		page
4.1	Binarized pixels for plate areas using global and adaptive threshold	62
4.2	The computation time for Sobel and VEDA	66
4.3	The percentage of success and failure detection (Dataset 1)	74
4.4	The processing times for the seven stages in the proposed method	74
4.5	Comparison of location rates between CARPET and the CLPD methods	77
4.6	CARPET vs. CLPD in different conditions	78

LIST OF FIGURES

Figure		page
2.1	The vertical Sobel edge detector mask	10
3.1	Flowchart of the proposed method	30
3.2	Hardware configuration and installation	31
3.3	The color input image conversion to gray scale	33
3.4	The image binarization	35
3.5	The four-cases for converting center pixel to foreground value	37
3.6	Unwanted Lines Elimination Algorithm output	38
3.7	The density values of a Cartesian grid	39
3.8	Sobel convolution kernels for x and y components	40
3.9	The design of the proposed mask	42
3.10	The intersection of black-white and white-black areas	43
3.11	Vertical Edge Detection Algorithm output	44
3.12	Vertical Edge Detection Algorithm output form	44
3.13	Highlight Desired Details output using NAND-AND operations	46
3.14	Highlight Desired Details output	47
3.15	No. of horizontal lines vs. group	49
3.16	Output of drawing candidate regions boundaries	51
3.17	Candidate Regions Extraction flowchart	51
3.18	Draw lines for some columns in candidate regions	53
3.19	Candidate region columns vs. blackness frequency	53
3.20	Both candidate regions' columns vs. blackness frequency	54

3.21 K-value (K≥0.5) 55

3.22 K-value (K≥0.4) 56

3.23 K-value (K≥0.3) 56

3.24 Plate detection 57

3.25 Plate region detection 58

3.26 Plate Region Selection and Detection flowchart 59

4.1 Image binarization using global and adaptive thresholding 61

4.2 The number of binarized plate pixels per each sample 63

4.3 Sobel and VEDA implementation steps 65

4.4 Sobel vs. VEDA processing time 67

4.5 Results of applying Sobel and VEDA 68

4.6 Output forms for vertical edges 70

4.7 Samples of images used in experimental 73

4.8 The total numbers of success and failure detection (Dataset 1) 74

4.9 The average processing time for Dataset 1 74

4.10 The enhancement of detection rate before and after K-factor 75

4.11 Examples of failure to find license plate 76

LIST OF ABBREVIATIONS

AT	Adaptive Thresholding
ALPR	Automatic License Plate Recognition
BPNN	Back Propagation Neural Network
CARPET	CAR Plate Extraction Technology
CRE	Candidate Region Extraction
CLPD	Car License Plate Detection
CLPDRS	Car License Plate Detection and Recognition System
CLPR	Car License Plate Recognition
FFNN	Feed Forward Neural Network
FL	Fuzzy Logic
GT	Global Thresholding
HDD	Highlight Desired Details
HV	horizontal-to-vertical
HT	Hough Transform
HLS	hue, lightness, and saturation
HSI	hue, saturation, and intensity
IT	Image Thresholding
ITS	Intelligent Transportation System
LPD	License Plate Detection
NN	Neural Network
PRD	Plate Region Detection
PRS	Plate Region Selection
RGB	Red, Green, and Blue
ROI	Region Of Interest
TDNN	Time-Delay Neural Network
ULEA	Unwanted Lines Elimination Algorithm
VEDA	Vertical Edge Detection Algorithm
VTS	Vehicle Tracking System

CHAPTER 1

INTRODUCTION

1.1 Introduction to Car License Plate Recognition System

A Car License Plate Detection and Recognition System (CLPDRS) is an image processing technology used to identify vehicles by capturing their car license plates. The car license plate recognition technology is known as automatic number-plate recognition, automatic vehicle identification, car license plate recognition or optical character recognition for cars.

The need for identification of a car is increasing for many reasons such as crime prevention, vehicle access control, and border control. To identify a car, features such as model, color, format, and license plate number can be used [1-3].

CLPDRS became an important area of research due to its usage in many applications, such as the payment of parking fee, highway toll fee, and traffic data collection [4, 5].

Usually, a CLPDRS consists of three parts: License Plate Detection (LPD), character segmentation and character recognition. Among these, license plate detection is the most important part because it affects the system's accuracy significantly [6].

1.2 Introduction to License Plate Detection

Automatic License Plate Recognition (ALPR) is an important aspect of applying computer techniques towards Intelligent Transportation Systems (ITS). In most cases, however, a LPD and extraction part must be performed correctly in order to build a complete and accurate CLPRS.

In recent years, there has been an increasing interest in using LPD as an important key for solving many problems in various applications [7], for example, LPD has been used to locate the license plate in order to build an accurate and fast CLPRS. However, far too little attention has been paid to use fast algorithms or low-resolution input images in CLPRSs. Therefore, there are many issues should be resolved in order to create successful and fast CLPRS, for example poor image quality, different plate sizes and designs, processing time, and background details and complexity.

An enhancement of Car License Plate Detection (CLPD) method performance such as reduction of computation time and algorithm complexity, or even build of LPR system with lower cost of its hardware devices, will make it more practical and usable than before.

1.3 Introduction to Vehicle Tracking Systems

Numerous vehicle tracking and pursue systems are using high performance cameras [8], and this leads to increase the cost of the system hardware and software as well.

While many methods have been proposed in various ITS applications, CLPDRS is usually based on image acquired at 640x480 resolution [9].

1.4 Introduction to Vertical Edge Detection

Vertical edge detection method is used in ALPR systems in order to extract the details of plate edges. Vertical edges are preferred in ALPR rather than horizontal edges because the vertical edges have rich information to be showed and highlighted in the plate region.

Vertical edge extraction and detection is one of the most crucial processes in CLPDS because it reduces the details. Thus, that would enhance the detection accuracy and processing time.

1.5 Motivation

LPD plays an important role in many important ITS applications such as ALPR, vehicle tracking systems, car parking systems, and highway toll fee. The robustness and accuracy of the plate detection step is crucial for the success of such systems. The efficiency of these systems depends significantly on the accuracy of the performance of the plate detection method. An improved license plate detector with a fast and accurate vertical edge detection algorithm helps to enhance the performance of the ITS applications based on LPD method.

1.6 Problem statement

One of the problems in CLPD methods is that there is no a selected method can be used for detecting license plates vastly in different places or countries, because of the difference in plate's style or design. In addition, there is a lack in the most of the recent CLPD methods in which their input images are used slightly. As known, a web camera is a very common device and it can be a good device for capturing the CLPD input images. The web camera usage leads to have low images' sizes and resolutions. Thus, a low computation time can be achieved in this case in such CLPD methods.

LPD is a very important process in all LPR systems. It is a very crucial process; because it affects the system's accuracy. The performance of LPR can be affected by LPD method's efficiency to give high or low detection rate. This thesis proposes a fast CLPD method in which a web-camera is used for acquiring the images. Therefore, simple LPR system with low input images resolution can be achieved by using the proposed method.

Vertical edges-based detection approach is one of the most used CLPD methods, and the enhancement of this approach is still continuing. In this thesis, an enhancement is proposed from computation time side is proposed in this work. This thesis proposes a fast Vertical Edge Detection Algorithm (VEDA) in order to reduce the computation time for vertical edge detection process.

1.7 Objectives

The objectives of this thesis are to:

- Propose a fast vertical edge detection algorithm (VEDA).
- Propose a CLPD method which can process low resolution input images.
- Evaluate the proposed method, and then compare it with a Malaysian car license plate detection method.

1.8 Thesis Organization

This thesis is divided into five chapters. In Chapter One, an introduction of the thesis is given. In Chapter Two, the theoretical background for this thesis is introduced. This chapter also reviews related work in this particular field including the concept of adaptive thresholding technique and vertical edge detectors. Chapter Three discusses the whole proposed CLPD methodology and explains in details on the proposed VEDA. In Chapter Four, final results are demonstrated and discussed. Also, the proposed CLPD and VEDA performances are evaluated. In this chapter, two comparisons of VEDA and the proposed CLPD method with two corresponding methods are discussed. The final chapter draws the conclusions and suggests further perspectives.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter introduces a brief study of adaptive thresholding techniques, and then introduces a study of edge detection and Sobel operator approach. a theoretical background of Car License Plate Detection (CLPD) technique is given in the next section. It also reviews the existing CLPD methods and techniques which have been used and proposed until present.

This chapter consists of five sections; the first section introduces adaptive thresholding techniques. Then, vertical edge detection methods and Sobel operator are reviewed. After that, the concepts of CLPD and its previous approaches are presented and discussed. This is followed by CLPD limitations in the fourth section. Finally, summary is given.

2.2 Adaptive Thresholding Techniques

Usually global thresholding is faster than adaptive thresholding, but global thresholding does not perform well in terms of output quality. Thus, many researches have been done in order to develop adaptive thresholding performance to save more processing time such as in [10-13].

In [12], a new method for adaptive document image binarization was proposed and implemented. It is a hybrid method, i.e. it uses both global and local information to decide the pixel label. Its performance is accurate and robust for image illumination, but it still needs more attention in term of computation time to be adequate for real time requirements. Later, a fast adaptive binarization algorithm that yields the same quality of binarization as before was proposed in [13]. Its computation time is close to the global thresholding methods. This algorithm combines the statistical constraints of the method proposed in [12] with integral images [14]. Another technique for real time adaptive thresholding using the integral image of the input was proposed and implemented in [10]. This technique is more robust to illumination changes in the image than others. The advantage of [10], it is simple and easy to implement and suitable for real time processing.

2.3 Edge Detection

Edge detection is the process of localizing pixel intensity transitions. The edge detection has been used by license plate detection, target tracking, segmentation, and etc. Therefore, the edge detection is one of the most important parts of image processing [15]. There mainly exists several edge detection methods (Sobel [16, 17], Prewitt [18], Roberts [19, 20], Canny [21]). These methods have been proposed for detecting transitions in images. Early methods determined the best gradient operator to detect sharp intensity variations [22]. Commonly used method for detecting edges is to apply derivative operators on images [15].

2.3.1 Sobel Theory

In computer vision, the Sobel operator is a simple edge detection algorithm using the first derivative of the intensity information [23].

Sobel [17] developed a filter known as the Sobel operator which is composed of two 3x3 masks, one vertical and one horizontal. The operator uses two 3x3 kernels convolved with the original image to produce a map of intensity gradient. The areas of highest gradient are where the intensity of the image changes rapidly over a few pixels, and are thus likely to represent edges.

Two convolution kernels are needed to detect the first-order derivative of both horizontal and vertical changes in a 2-dimensional image. If we define *A* as the source image, we can compute:

$$G_x = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} * A \quad and \quad G_y = \begin{bmatrix} +1 & +2 & +1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} * A \tag{2.1}$$

This can then be combined to give the overall magnitudes using Eq. (2.2):

$$G = \sqrt{{G_x}^2 + {G_y}^2} \tag{2.2}$$

Using this information, we can also calculate the gradient's direction from Eq. (2.3):

$$\Theta = \arctan\left(\frac{G_x}{G_y}\right) \tag{2.3}$$