

HARDWARE-ACCELERATED LOCALIZATION FOR AUTOMATED LICENSE
PLATE RECOGNITION SYSTEM

CHIN TECK LOONG

UNIVERSITI TEKNOLOGI MALAYSIA

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CHIN TECK LOONG

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For my beloved family.

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ABSTRACT

Automatic License Plate Recognition (ALPR) is a continuous process of extracting license plate information from a series of input images. Localization is an imperative stage in ALPR system because it extracts the sub image which contains the potential license plate for subsequent processing. Many ALPR systems are designed to operate on general purpose processor, in which the low degree of instruction and data level parallelism is not maximized, resulting in lower efficiency. Also, current ALPR system in the market is not modular and generalized to cater license plates from different nations with different languages and standards. This project proposes a multi-feature extraction algorithm for license plate localization catering various plate and environment variation factors, as well as hardware architecture to implement the algorithm with full modularity baseline. The proposed hardware architecture has been successfully modelled and implemented using System Verilog. It achieves an average speed up of $222\times$ across different test images compared to software-based algorithm and 100% matching the localization accuracy in software.

ABSTRAK

Pengenalan Plat Lesen Automatik (PPLA) adalah satu proses berterusan yang mengekstrak maklumat plat lesen daripada beberapa siri imej input. Lokalisasi adalah peringkat yang penting dalam sistem PPLA kerana ia memproses sub-imej yang mengandungi plat lesen untuk pemprosesan selanjutnya. Kebanyakan sistem PPLA direka bentuk untuk beroperasi menggunakan mikroprosesor serbaguna, di mana aturan sistem dan data yang rendah tidak dioptimumkan, mengakibatkan kecekapan sistem yang rendah. Sistem PPLA semasa di pasaran tidak dapat membezakan plat lesen dari negara-negara yang berbeza dari segi bahasa dan spesifikasi. Projek ini mencadangkan satu algoritma lokalisasi dalam menganalisa pelbagai jenis ciri imej input untuk faktor plat lesen dan persekitaran. Struktur senibina perkakasan juga dicadangkan untuk melaksanakan algoritma ini dengan suai garis dasar penuh. Sistem yang dicadangkan telah berjaya dimodelkan menggunakan Sistem Verilog. Ia mencapai kelajuan purata $222\times$ daripada seluruh imej cubaan apabila berbanding dengan algoritma berasaskan perisian, dan 100% terbukti sama dengan ketepatan perisian.

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LIST OF ABBREVIATIONS

ALPR	-	Automatic License Plate Recognition
ASIC	-	Application Specific Integrated Circuit
ASM	-	Algorithmic State Machine
CCA	-	Connected Component Analysis
CCL	-	Connected Component Labelling
CCTV	-	Closed-Circuit Television
DFT	-	Discrete Fourier Transform
DSP	-	Digital Signal Processing
DUT	-	Device Under Test
EAV	-	End of Active Video
EDH	-	Error Detection and Handling
FDA	-	Fully Dedicated Architecture
FPGA	-	Field Programmable Gate Array
FSM	-	Finite State Machine
HLS	-	Hue-Luminance-Saturation
IC	-	Integrated Circuit
IP	-	Intellectual Property
ITU	-	International Telecommunication Union
RGB	-	Red-Green-Blue
SAV	-	Start of Active Video
SCW	-	Sliding Concentric Windows
SOM	-	Self-Organizing Map
SVN	-	Support Vector Machine
VEDA	-	Vertical Edge Detection Algorithm
VQ	-	Vector Quantization
WT	-	Wavelet Transform

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The number of motor vehicles on the road increases over the years and it has driven an urgent need to manage these vehicles systematically and efficiently. This results in the emergence of transportation related applications such as traffic monitoring and surveillance, congestion avoidance and control, and automatic electronic payment for toll and parking fee.

Most of these intelligent transportation systems utilize image processing algorithms to process still images or video frames captured remotely. Advanced computer vision technologies in recent years have enabled the development of various efficient software-based algorithms in this field. Researches published in [1] and [2] have provided complete study of computer vision techniques in transportation domain. Many current works utilize neural networks to process and analyze the torrents of traffic images [3,4], but there are very few real time devices being developed.

One of the critical stages in intelligent transportation systems is Automatic License Plate Recognition (ALPR). ALPR is a continuous process of extracting information of license plate from the raw input images captured remotely. They can be color or black and white. There are many different ways of implementing an ALPR system, which is one of the focused research area in past decade [5–8]. At present, many successful commercial software-based ALPR systems are available in the market, but most of them require dedicated camera systems which provide video input acquired under controlled environment [4]. In other words, quality of the acquired images is indeed critical for an ALPR system.

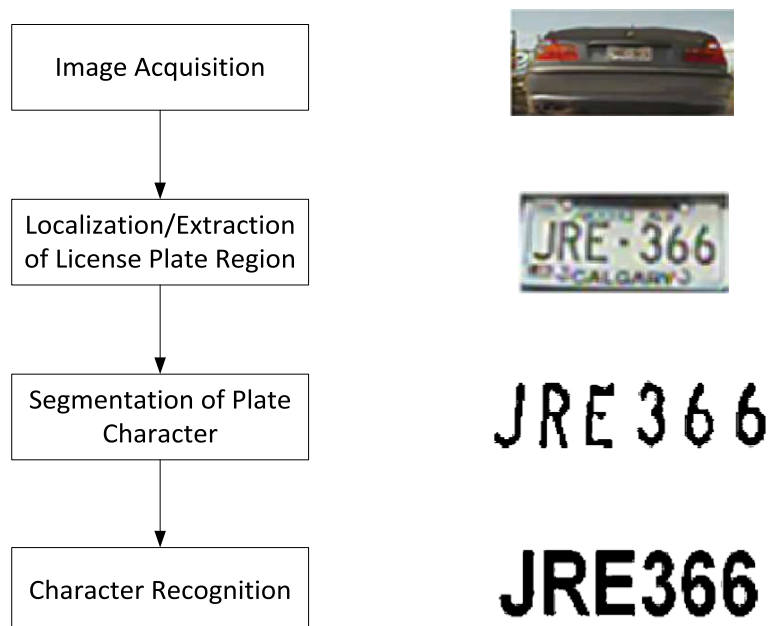


Figure 1.1: Overview of ALPR systems [5].

Another imperative requirement for an efficient ALPR is the processing time. Real time processing is required so that the system will not miss out a single frame in the continuous video stream. The definition of real time is very much dependent on the target traffic flow. For example, the throughput of an ALPR system for highway monitoring ought to be higher than an ALPR system deployed in the residential area with lighter traffic. On a road in residential area, the video stream of 20 frames per second is sufficient for real-time analysis, but this is insufficient for highway with speed limit of 110 km/hour [9]. ALPR systems are generally composed of four processing stages [5] as depicted in Figure 1.1. Table 1.1 provides short descriptions of each ALPR's stage.

1.2 Motivation and Problem Statement

Even this area has been actively researched, many areas of improvement are still possible on existing ALPR systems [5]. Currently, most of the ALPR algorithms are developed based on specific constrained conditions. The implicit assumption for these ALPR systems is that the input video is obtained in a controlled capture environment, via a dedicated camera with high speed and high resolution [4]. A modular and generalized solution which is able to cater license plates from different nations with different languages and standards does not exist at present.

Table 1.1: Summary of ALPR Stages.

ALPR Stage	Descriptions
Image Acquisition	<ul style="list-style-type: none"> - Involves capturing of input images using a camera. - Heavily dependent on camera parameters: resolution, shutter speed, exposure, light, and orientation. - Depends on hardware performance, not many researches have been carried out in this stage. - ALPR's main objective is to eliminate hardware dependency in this stage.
Localization of License Plate Region	<ul style="list-style-type: none"> - To identify the potential license plate region with some image features. - The input is raw image acquired by the camera. - The output is sub-image of extracted license plate or the coordinates bounding the sub-image. - Critical in overall ALPR's recognition accuracy.
Segmentation of Plate Character	<ul style="list-style-type: none"> - Involves extracting characters from localized plate region. - Resolve the undesired problems on the localized sub image which are inherited from previous stage such as tilt and non-uniform brightness.
Character Recognition	<ul style="list-style-type: none"> - Involves pattern matching algorithm between the segmented characters and a predefined database. - Accuracy issue due to non-uniform sizes of the extracted character. - Hence, the characters are typically resized before recognition is performed.

Many advanced software-based ALPR systems have been designed to operate on a general purpose processor. The general purpose processor is not efficient at low degree of instruction and data level parallelism to perform real time computation resulting in lower efficiency compared to dedicated hardware with pipelining design [10]. Besides, the general purpose processors require higher power consumption and cost. Hence, there is an intensified need of ALPR system with higher computing power, but lower energy consumption to handle the exponential growth of vehicles [11]. Therefore, hardware implementation of ALPR algorithms has gained much attention during past decade along with the advancement of on-chip processing technology such as Field Programmable Gate Array (FPGA) and Application Specific Integrated Circuit (ASIC).

Analyzing the three compute intensive stages of an ALPR system, it was proven in [12, 13], that the recognition rate can be increased by applying prior knowledge on the potential characters in segmentation stage. Also, certain amount of pre-stored information is required to achieve high accuracy in character recognition stage, which

in turns translates to memory requirements [5]. Due to the memory requirement of these two stages, it is more efficient to have them remain in the backend process running on general purpose processors. Hence, there is strong motivation to explore the feasibility of hardware based localization to realize a real-time ALPR system. It is very critical to locate the potential local area containing only license plates and limit the backend compute intensive algorithms operating only on the pixels within this local area [14].

1.3 Aim and Objectives

The aim of this project is to design and develop hardware accelerated localization architecture for ALPR system. To achieve the aim, the objectives of this project are:

1. To propose a multi-feature extraction algorithm for license plate localization catering various plate and environment variation factors. This algorithm needs to be simplified for hardware implementation without compromising localization accuracy.
2. To design hardware based fully dedicated architecture (FDA) to implement the proposed algorithm with full modularity baseline. This follows by performance analysis and benchmark of the proposed FDA with related works.

1.4 Project Scope

Out of the four ALPR stages described in Section 1.1, this project focuses only on the localization stage. The segmentation and recognition stages are more complicated which require training based on a priori database and hence they are more efficient to be implemented on backend server with higher memory requirements. Hence, the feasibility of accelerating localization stage with dedicated hardware architecture is explored in this project.

It involves analysis of various localization algorithms in term of efficiency, accuracy, and feasibility for hardware implementation, follows by a selection of critical features to be integrated into a multi-feature extraction algorithm for license plate

localization. This newly proposed algorithm is developed to address various plate and environment variations which severely impair ALPR's performance. The data format of the input image used in this project is in accordance to Recommendation ITU-R BT.656-4 which describes the means of interconnecting digital television equipment operating on the 525-line or 625-line standards, complying with the 4:2:2 encoding parameters as defined in Recommendation ITU-R BT.601.

A FDA is proposed to implement the multi-feature extraction algorithm for license plate localization. This FDA only extracts a subset of information from the real time video frames acquired by ALPR's front end camera nodes. In this case, information required to be sent to the backend recognition system only consists of potential localized license plate region of smaller resolution. This system decreases the bandwidth requirement between the smart camera and the backend server. Subsequently, performance analysis and algorithm profiling of both hardware and software are performed in term of execution time, localization accuracy and hardware resource utilization.

1.5 Report Organization

This report is divided into six chapters to present the entire project in an organized manner.

In Chapter 2, the theoretical background and related works involved in this project are described. It includes an overview on ALPR system, before focuses on detail discussion of related works in license plate localization and hardware implementation of various localization algorithms. It also includes detail description of Recommendation ITU-R BT.656-4 – the video standard used in this project.

In Chapter 3, methodologies involved in this project are described. It illustrates in detail the five main stages of methodology involved in this project: algorithm development on software-based platform, algorithm validation and verification, algorithm profiling, hardware architecture design, and hardware simulation and verification. In order to give the reader a further insight on this project, the softwares used throughout the course of this project are described in this chapter as well.

In Chapter 4, the details of the proposed localization algorithm with multi-feature extraction is presented, followed by a series of analysis in term of accuracy based on data set used in this project. Also, overall performance of the proposed localization algorithm developed in MATLAB® is profiled and discussed.

In Chapter 5, the reader will be briefed on the design consideration involved in this project, followed by detailed architectural descriptions of every major hardware module designed. Also, a series of timing diagrams obtained from the simulation process are presented. These simulation results will be analyzed and discussed in this chapter in order to verify the functionality and evaluate the performance of the proposed FDA. A comparison and benchmark summary of the proposed FDA with previous works is also included.

In Chapter 6, the conclusion of this project is made. Also included in this chapter are the limitations of this project and recommendations for future works.

REFERENCES

1. Veeraraghavan, H., Masoud, O. and Papanikolopoulos, N. P. Computer Vision Algorithms for Intersection Monitoring. *Intelligent Transportation Systems, IEEE Transactions on*, June 2003. 4(2): 78–89.
2. Loce, R. P., Bernal, E. A., Wu, W. and Bala, R. Computer Vision in Roadway Transportation Systems: A Survey. *Journal of Electronic Imaging* 22(4), Dec 2013. (041121).
3. Caner, H., Gecim, H. S. and Alkar, A. Z. Efficient Embedded Neural-Network-Based License Plate Recognition System. *Vehicular Technology, IEEE Transactions on*, Sep 2008. 57(5): 2675–2683.
4. Sarfraz, M. S., Shahzad, A., Elahi, M. A., Fraz, M., Zafar, I. and Edirisinghe, E. A. Real-time Automatic License Plate Recognition for CCTV Forensic Applications. *J Real-Time Image Proc*, 2013. 8: 285–295.
5. Du, S., Ibrahim, M., Shehata, M. and Badawy, W. Automatic License Plate Recognition (ALPR): A State-of-the-Art Review. *Circuits and Systems for Video Technology, IEEE Transactions on*, Feb 2013. 23(2): 311–325.
6. Liu, G., Ma, Z., Du, Z. and Wen, C. The Calculation Method of Road Travel Time Based on License Plate Recognition Technology. *Advances in Information Technology and Education Communication in Computer and Information Science*, 2011. 201: 385–389.
7. Chiou, Y.-C., Lan, L. W., Tseng, C.-M. and Fan, C.-C. Optimal Locations of License Plate Recognition to Enhance the Origin-Destination Matrix Estimation. *Asian Transport Studies*, 2012. 2: 80–92.
8. Anagnostopoulos, C.-N. E., Anagnostopoulos, I. E., Psoroulas, I. D., Loumos, V. and Kayafas, E. License Plate Recognition From Still Images and Video Sequences: A Survey. *Intelligent Transportation Systems, IEEE Transactions on*, Sep 2008. 9(3): 377–391.
9. Arth, C., Limberger, F. and Bischof, H. Real-Time License Plate Recognition on an Embedded DSP-Platform. *Computer Vision and Pattern Recognition, 2007. CVPR '07. IEEE Conference on*, Jun 2007.

10. Bellas, N., Chai, S. M., Dwyer, M. and Linzmeier, D. FPGA Implementation of a License Plate Recognition SoC using Automatically Generated Streaming Accelerators. *Parallel and Distributed Processing Symposium, 2006. IPDPS 2006. 20th International*, Apr 2006.
11. Kanamori, T., Amano, H., Arai, M., Konno, D., Nanba, T. and Ajioka, Y. Implementation and Evaluation of a High Speed License Plate Recognition System on an FPGA. *Computer and Information Technology, 2007. CIT 2007. 7th IEEE International Conference on*, Oct 2007.
12. Chang, S.-L., Chen, L.-S., Chung, Y.-C. and Chen, S.-W. Automatic License Plate Recognition. *Intelligent Transportation Systems, IEEE Transaction on*, Mar 2004. 5(1): 42–53.
13. Jia, X., Wang, X., Li, W. and Wang, H. A Novel Algorithm for Character Segmentation of Degraded License Plate Based on Prior Knowledge. *Automation and Logistics, 2007 IEEE International Conference on*, Aug 2007: 249–253.
14. Yang, S.-Y., Lu, Y.-C., Chen, L.-Y. and Cherng, D.-C. Hardware-accelerated Vehicle License Plate Detection at High-definition Image. *Robot, Vision and Signal Processing (RVSP), 2011 First International Conference on*, Nov 2011: 106–109.
15. Faradji, F., Rezaie, A. H. and Ziaratban, M. A Morphological-Based License Plate Location. *Image Processing, 2007. ICIP 2007. IEEE International Conference on*, Sep 2007. 1: 57–60.
16. Sanyuan, Z., Mingli, Z. and XiuZi, Y. Car Plate Character Extraction under Complicated Environment. *Systems, Man and Cybernetics, 2004 IEEE International Conference on*, 2004. 5: 4722–4726.
17. Yang, F. and Ma, Z. Vehicle License Plate Location based on Histogramming and Mathematical Morphology. *Automatic Identification Advanced Technologies, 2005. Fourth IEEE Workshop on*, Oct 2005: 89–94.
18. Suryanarayana, P. V., Mitra, S. K., Baneree, A. and Roy, A. K. A Morphology Based Approach for Car License Plate Extraction. *INDICON, 2005 Annual IEEE*, Dec 2005: 24–27.
19. Wu, H.-H. P., Chen, H.-H., Wu, R.-J. and Shen, D.-F. License Plate Extraction in Low Resolution Video. *Pattern Recognition, 2006. ICPR 2006. 18th International Conference on*, 2006. 1: 824–827.
20. ke Xu, H., hua Yu, F., hua Jiao, J. and sheng Song, H. A New Approach of the Vehicle License Plate Location. *Parallel and Distributed Computing*,

- Applications and Technologies, 2005. PDCAT 2005. Sixth International Conference on*, Dec 2005: 1055–1057.
21. Anagnostopoulos, C. N. E., Anagnostopoulos, I. E., Loumos, V. and Kayafas, E. A License Plate-Recognition Algorithm for Intelligent Transportation System Applications. *Intelligent Transportation Systems, IEEE Transactions on*, Sep 2006. 7(3): 377–392.
 22. Zunino, R. and Rovetta, S. Vector Quantization for License-Plate Location and Image Coding. *Industrial Electronics, IEEE Transactions on*, Feb 2000. 47(1): 159–167.
 23. R.Parisi, Claudio, E., G.Lucarelli and G.Orlandi. Car Plate Recognition by Neural Networks and Image Processing. *Circuits and Systems, 1998. ISCAS '98. Proceedings of the 1998 IEEE International Symposium on*, Jun 1998. 3: 195–198.
 24. Hsieh, C.-T., Juan, Y.-S. and Hung, K.-M. Multiple License Plate Detection for Complex Background. *Nonlinear Signal and Image Processing, 2005. NSIP 2005. Abstracts. IEEE-Eurasip*, May 2005.
 25. Shi, X., Zhao, W. and Shen, Y. Automatic License Plate Recognition System Based on Color Image Processing. *Computational Science and Its Application - ICCSA 2005*, 2005. 3483: 1159–1168.
 26. Cheng, Y. Mean shift, Mode Seeking, and Clustering. *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, Aug 1995. 17(8): 790–799.
 27. Matas, J. and Zimmermann, K. Unconstrained Licence Plate and Text Localization and Recognition. *Intelligent Transportation Systems, 2005. Proceedings. 2005 IEEE*, Sep 2005: 225–230.
 28. Alegria, F. and Girao, P. S. Vehicle Plate Recognition for Wireless Traffic Control and Law Enforcement System. *Industrial Technology, 2006. ICIT 2006. IEEE International Conference on*, Dec 2006: 1800–1804.
 29. Hontani, H. and Koga, T. Character Extraction Method without Prior Knowledge on Size and Position Information. *Vehicle Electronics Conference, 2001. IVEC 2001. Proceedings of the IEEE International*, Sep 2001: 67–72.
 30. Setumin, S., Sheikh, U. U. and Abu-Bakar, S. Character-Based Car Plate Detection and Localization. *Information Sciences Signal Processing and their Applications (ISSPA), 2010 10th International Conference on*, May 2010: 737–740.
 31. Viola, P. and Jones, M. Robust Real-Time Object Detection. *International*

- Journal of Computer Vision*, 2001.
32. Xie, M., Fu, H. and Liu, Z. One Design Method of License Plate Recognition System with High Recognition Rate. *IT in Medicine and Education, 2008. ITME 2008. IEEE International Symposium on*, Dec 2008: 44–49.
 33. Musoromy, Z., Bensaali, F., Ramalingam, S. and Pissanidis, G. Comparison of Real-Time DSP-Based Edge Detection Techniques for License Plate Detection. *Information Assurance and Security (IAS), 2010 Sixth International Conference on*, Aug 2010: 323–328.
 34. Zhai, X., Bensaali, F. and Ramalingam, S. Improved Number Plate Localisation Algorithm and Its Efficient Field Programmable Gate Arrays Implementation. *Circuits, Devices and Systems, IET*, Mar 2013. 7(2): 93–103.
 35. Recommendation ITU-R BT.656-4, 2014. URL <http://www-inst.eecs.berkeley.edu/~cs150/Documents/ITU656.PDF>.
 36. Recommendation ITU-R BT.601-4, 2014. URL <http://www-inst.eecs.berkeley.edu/~cs150/Documents/ITU601.PDF>.
 37. Medialab LPR Database, 2014. URL <http://www.medialab.ntua.gr/research/LPRdatabase.html>.
 38. Arth, C., Bischof, H. and Leistner, C. TRICam - An Embedded Platform for Remote Traffic Surveillance. *Computer Vision and Pattern Recognition Workshop, 2006. CVPRW '06. Conference on*, Jun 2006: 125.
 39. Hongliang, B. and Changping, L. A Hybrid License Plate Extraction Method Based on Edge Statistics and Morphology. *Pattern Recognition, 2004. ICPR 2004. Proceedings of the 17th International Conference on*, Aug 2004. 2: 831–834.