اونيۏرسيتي تيكنيكل مليسيا ملاك

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Electronic and Computer Engineering

DEVELOPMENT OF ALGORITHMS FOR VEHICLE CLASSIFICATION AND SPEED ESTIMATION FROM DYNAMIC SCENES BY ON-BOARD CAMERA USING IMAGE PROCESSING TECHNIQUES

Nur Shazwani binti Aminuddin

Master of Science in Electronic Engineering

2018

DEVELOPMENT OF ALGORITHMS FOR VEHICLE CLASSIFICATION AND SPEED ESTIMATION FROM DYNAMIC SCENES BY ON-BOARD CAMERA USING IMAGE PROCESSING TECHNIQUES

NUR SHAZWANI BINTI AMINUDDIN

A thesis submitted
in fulfillment of the requirements for the degree of Master of Science
in Electronic Engineering

Faculty of Electronic and Computer Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2018

DECLARATION

I declare that this thesis entitle "Development of Algorithms for Vehicle Classification and Speed Estimation from Dynamic Scenes by On-Board Camera Using Image Processing Techniques" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : NUR SHAZWANI BINTI AMINUDDIN

Date : ....12/04/2018..............................

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Electronic Engineering.

Signature : ....

Supervisor Name : DR. MASRULLIZAM BIN MAT IBRAHIM

Date : 12/4/2018

DEDICATION

To

my dear self,

my parents Adibah and Aminuddin,

my siblings Mimi, Na, Den, and Nish

ABSTRACT

Vehicle assistance system applications benefit the drivers and passengers to promote better and safer driving situations. In terms of usability of dash camera, most vehicle owners pre-installed the camera as a personal safety purpose to record the path they went through. The wide availability of various models of the dash cameras on the market, however, lacks in intelligence to process the information that can be obtained from the camera technology system itself. Moreover, in most studies for Intelligence Transport System (ITS), the implementation of static camera, for example CCTV, is popular thus, it is an encouragement for improvement to develop a vehicle assistance system using dynamic camera scenes. The main purpose of this research was to develop a vehicle detection, vehicle classification, and vehicle speed estimation system in dynamic scenes fully by image processing technique. The scope of this research covered Malaysia highway in Skudai, Johor; Ayer Keroh, Melaka and Kajang, Selangor. Video database of these highway areas was recorded by the on-board camera unit placed on the front dashboard area of the host vehicle. Image dataset was collected with positive image sets containing four vehicle classes namely car, lorry, bus, and motorcycle. It was decided that the technique for vehicle detection were Haar-Like and Cascade Classifier while vehicle classification was based on the ratio characteristics of the vehicle detected. The use of ratio value was an added advantage for the classification process since the prepared image dataset were based on each vehicle class dimension and the ratio value are the uniqueness property for each vehicle class. Speed estimation of the vehicle started with host vehicle speed estimation by lane detection technique since the road lane was the most consistence moving object inside the video region. The Host vehicle distance measurement used the broken lane detection and for a scale factor calculation, the width of the highway lanes was calculated by measuring the lane width inside the image and calibrated with real value in meter of the lanes stated by (Jabatan Kerja Raya, 1997). Detected vehicle speed measurements were based on its centroid tracking measurements. Result analysis on accuracy measurement in vehicle detection system obtained 0.93 true positive rates from 300 vehicles presented in the video data. Further analysis in vehicle classification was proved to obtain true positive rate of 0.98 for car class, 0.89 for lorry class, 0.89 for bus class, and 0.75 for motorcycle class. For analysis of speed estimation achieved with the average percentage 6.42% for speed error of host vehicle tested on 10 different videos. In detected vehicle, its speed estimations were based on the host vehicle speed calculation by observation its position and motion behavior in comparison with the host vehicle speed value. Overall, these development indicated that image processing has the ability to visualize the surrounding area for drivers and passengers that was near to real human visions, a contribution to human-machine interactions that can be beneficial.

ABSTRAK

Aplikasi sistem bantuan kenderaan memberi manfaat kepada pemandu dan penumpang untuk menggalakkan gaya pemanduan yang lebih selamat. Dari segi penggunaan kamera papan pemuka, kebanyakan pemilik kenderaan melengkapi kenderaan mereka dengan kamera tersebut bertujuan untuk merakam laluan yang mereka lalui sebagai langkah keselamatan. Pelbagai variasi model kamera papan pemuka boleh didapati di pasaran, namun, kekurangan teknologi pada spesifikasi kamera tersebut perlu ditingkatkan. Selain itu, kebanyakkan kajian yang terlibat dalam pembinaan aplikasi sistem pengangkutan, menggunakan teknologi kamera statik seperti CCTV. Oleh itu, penambahbaikan amat perlu dengan membangunkan sistem bantuan kenderaan dengan menggunakan kamera dinamik. Tujuan utama kajian ini dijalankan adalah untuk membangunkan sistem aplikasi pengesanan kenderaan, pengklasifikasi kenderaan, dan menganggar kelajuan kenderaan bagi teknik pemprosesan imej menggunakan babak dinamik lebuh raya. Skop kajian ini meliputi lebuh raya Malaysia sekitar Skudai, Johor, Ayer Keroh, Melaka dan Kajang, Selangor. Pangkalan data video mengandungi rakaman video sekitar lebuh raya Malaysia direkod oleh kamera papan pemuka yang diletakkan di bahagian cermin papan pemuka kenderaan utama. Tambahan lagi, koleksi dataset imej positif mengandungi empat kelas kenderaan iaitu kereta, lori, bas dan motosikal. Teknik digunakan untuk mengesan kenderaan adalah ciri-ciri Haar-like dan Pengelas Cascade manakala teknik pengklasifikasi kenderaan adalah berdasarkan pengiraan nisbah kenderaan yang dikesan. Penggunaan nisbah sebagai pengklasifikasi adalah satu kelebihan kerana dataset imej positif kenderaan yang disediakan adalah berdasarkan dimensi bagi setiap jenis kenderaan dan nisbahnya sebagai faktor unik untuk mengelas kenderaan. Bagi teknik anggaran kelajuan kenderaan, teknik pengesanan penanda lorong lebuh raya digunakan. Hal ini kerana, penanda lorong lebuh raya bergerak dengan konsisten di dalam video, menjadikannya sebagai pengukur nilai jarak pengiraan kelajuan kenderaan utama. Pengiraan skala faktor digunakan untuk mengira penukaran nilai dari nilai piksel lebar lebuh raya didalam imej kepada nilai dunia sebenar lebar lebuh raya berdasarkan (Jabatan Kerja Raya, 1997). Bagi pengiraan kelajuan kenderaan yang dikesan, nilai centroid adalah komponen utama untuk mengira jarak yang dilalui kenderan yang dikesan. Analisis keputusan adalah berdasarkan kadar positif pengesanan sistem dimana kadar positif benar adalah 0.93 daripada 300 kenderaan yang terdapat di dalam video. Analisis selanjutnya adalah prestasi pengklasifikasi kenderaan yang dibina, keputusan menunjukkan kadar positif benar ialah 0.98 bagi kelas kereta, 0.89 bagi kelas lori, 0.89 bagi kelas bas dan 0.75 bagi kelas motosikal. Bagi analisis penganggaran kelajuan, 10 video telah digunakan dan dari analisis kelajuan, purata kesilapan anggaran kelajuan memperoleh sebanyak 6.42%. Keputusan analisis bagi kelajuan untuk kereta yang dikesan adalah berdasarkan perbandingan perubahan jarak dan gerakan kenderaan tersebut dengan kenderaan utama. Secara keseluruhan, pembangunan menggunakan teknik imej pemprosesan adalah hampir sama dengan visi sebenar manusia, oleh itu,ianya menyumbang kepada kemudahan interaksi antara manusia dan mesin.

ACKNOWLEDGEMENTS

I am grateful to Allah for good health throughout this research. I am very blessed with the completion of this thesis. Hereby, I would like to express my sense of gratitude to one and all, who directly or indirectly have lent their hand in completing this project and thesis. I wish to express my gratitude to my research supervisor, Dr. Masrullizam Bin Mat Ibrahim. I am very much thankful to him for valuable guidance and keen interest with encouragement during my research period despite with busy schedules. Also, a great thank you to my second supervisor Madam Nursabillilah binti Mohd Ali from Faculty of Electric (FKE). The supervisors have been such a good guider with appropriate tips and knowledge during my research progress. Special thanks to all my family members who tried their best to give a lot of encouragement and support. I am also grateful to my friends and lab mates who supported and helped me through this research period until its end. Finally, I would like to thank Universiti Teknikal Malaysia Melaka (UTeM) and Ministry of Higher Education for supporting this research under RAGS/1/2015/TK0/FKEKK/02/B00101 and MyBrain UTeM.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADAS	-	Advanced Driver Assistance System
CCTV	-	Closed-Circuit Television
CNN	-	Convolutional Neural Network
ELM	-	Extreme Learning Machine
GDSM	-	Genetic Dynamic Saliency Map
GDVM	-	Grey Differential Value Method
HDBN	-	Hybrid Dynamic Bayesian Network
HOG	-	Histogram of Oriented Gradient
ITS	-	Intelligence Transport System
KLT	-	Kanade–Lucas–Tomasi
LIDAR	-	Laser Identification Detection and Ranging
LNMS	-	Linear Normalization with Mean Shift
MMR	-	Make and Model Recognition
RADAR	-	Radio Detection and Ranging
RBF	-	Radial Basis Function
RGB	-	Red-Green-Blue
ROC		Receiver Operating Characteristic
ROI	-	Region of Interest
SC	-	Sparse Coding
SIFT	-	Scale Invariant Feature Transformation

SURF	-	Speeded up Robust Features
SVM	-	Support Vector Machine

LIST OF PUBLICATIONS

1. A, N.S., Ibrahim, M.M., Ali, N.M., and Y, N.F.I., 2016. Vehicle Detection Based o n Underneath Vehicle Shadow Using Edge Features. *IEEE International Conference on Control System, Computing and Engineering (ICCSCE2016)*, pp.25–27.
2. A, N.S., Ibrahim, M.M., Ali, N.M., Radzi, S.A., Darsono, A.M., and Chiew, W.Y., 2017. Road Triangle Detection for Non-Road Area Elimination Using Lane Detection and Image Multiplication. *Journal of Telecommunication Electronic and Computer Engineering*, 9 (2), pp.73–77.
3. Aminuddin, N.S., Ibrahim, M.M., Ali, M., Radzi, S.A., Hidayat, W., and Saad, M., 2017. A New Approach to Highway Lane Detection by Using Hough Transform Technique. *Journal of Information and Communication Technology (JICT)*, 2 (2), pp.244–260.
4. A, N.S., Ibrahim, M.M., and Ali, N.M., 2017. Comparison of Forward Vehicle Detection Using Haar-like features and Histograms of Oriented Gradients (HOG) Technique for Feature Extraction in Cascade Classifier. *Journal of Telecommunication Electronic and Computer Engineering*, 9 (2), pp.101–105.

CHAPTER 1

INTRODUCTION

1.1 Project Background

Intelligence Transport System (ITS) for vehicular system in various applications has emerged as a demanding project in a recent development of vehicular area. It can be focused on many categories and applications such as vehicle detection, road lane marks detection, and road obstacle detection. The advantages provided from the existence of intelligence system for drivers that they are aware of their driving environments thus, promote safe driving habits and environments. One example of ITS is an obstacle detection system, in which the system functioning with the vehicular on-board units that detect the surroundings. The system will notify vehicles' motion status to update the driver and give warning for assisting driver on the obstacle ahead that needs to be avoided (Wu et al., 2014). Therefore, naturally the adding features of driving assistance by an intelligence system for driver are a great improvement.

On the contrary, one of the rising demands of on-board units that drivers often use is the dash camera. Dash camera is simply a camera mounted at the dash board area of the car. It is designed to record sounds and images from the drivers' point of view while driving as shown in Figure 1.1. The purpose of having the camera installed in vehicles is to record every detailed information from scenes that take place on the road. Various types and resolution up to 2560 x 1440 (4K) of the camera specification are available in the market with affordable prices. Notable reason from the drivers to have this in their vehicle is simply for personal safety measures.

Figure 1.1: Dash Camera

Owing to the innovation of the dash camera, algorithms can be developed by the implementation of video footages of Malaysia road highways recorded by the on-board dash camera. Since the camera captures and records the images of the road scenes, the use of image processing technique on the video can be applied to analyse the road area. From the analysis, many parameters can be obtained from the video sequences such as a number of vehicles, turning traffic flows at intersections, speed measurements and many more (Chong et al., 2013). Generally, this research aimed to develop an algorithm system that consisted of a combination of systems in vehicle detection, vehicle classification and vehicle speed estimations.

Basically, image processing techniques consist of flow steps that need to be followed by each of its sequence to achieve the best results. Through this flow, a full system combination of vehicle detection, vehicle classification and vehicle speed estimation can be achieved. Figure 1.2 shows a basic flow of the algorithm development by using image processing technique followed by this research. The choices made for the technique depend on the reliability of each component of the system to each other based on characteristics needed by each component.

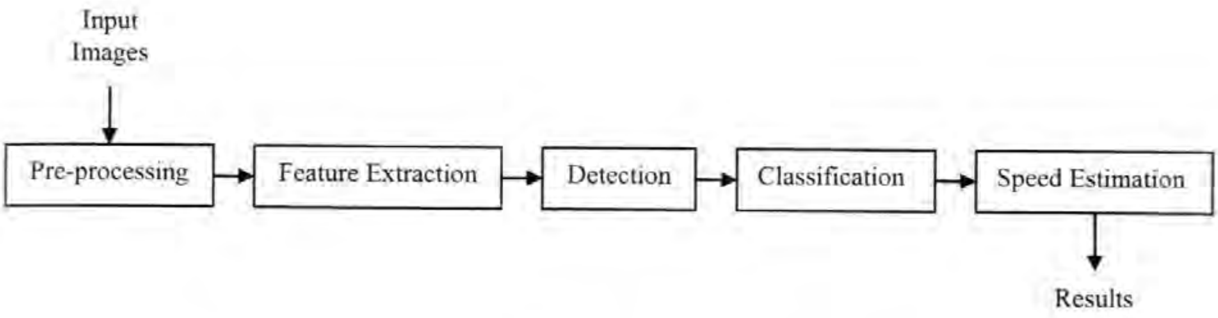

Figure 1.2: Basic Flow of Image Processing Techniques

From the flow, image pre-processing is the first stage of the system. The image data input undergoes this stage to enhance the main feature of the vehicle by improving its appearance. Next stage is the feature extraction where the unique features that best describe each vehicle type are extracted. The aim for feature extraction is to group the vehicle type with the same and different categories in its class based on its feature property. Extracted features are then passed into stages that work by classifying the vector and train them to produce a final vehicle detector system.

In recent time, a technique of image processing for vehicle detection development is commonly adapted by the use of static camera, for example CCTV, placed on the road side to monitor traffic conditions (Battiato et al., n.d.; Leon and Hirata Jr, 2012). For that purpose, the backgrounds captured in the camera are almost static. This approach basically uses a background subtraction method based on the difference of motion of the target object and the almost static background (Brutzer et al., 2011) (Sirikuntamat and Algorithm, 2015). In contrast to the dynamic background approach, the background subtraction is not applicable. In order to distinguish the background and foreground in a dynamic scene, motion flow classification by (Chen and Wu, 2015) can be applied. Optical flow feature points on an edge of image are produced by applying canny edge operator and Lucas-Kanade Pyramid Model, used to calculate the optical flow information for distinguishing the motion between the background and the vehicle.

Furthermore, current study for vehicle speed estimation applied the use of RADAR (Radio Detection and Ranging) methods (Jeng et al., 2014). The RADAR is placed at the roadside to cover multiple lanes of the road instead of install it in parallel to the direction of traffic. Unfortunately, it is only able to detect a forward single lane which only detects the speed of single forward vehicle in the radar range. On the contrary, image processing techniques in vehicle speed estimation, by (Gupta, Pratishtha, G. N. Purohit, 2014) estimated the vehicle speed by using a centroid method. Vehicles detected were tagged with centroid that followed the movement of vehicles. The distances travelled by the centroid were calculated representing the distance of the vehicles. Distances calculated were included with a specific amount of time to obtain the speed values. As a comparison to RADAR method, the image processing approach undoubtedly covers more, in terms of distance and angle that radar has been able.

1.2 Problem Statement

Prior to the existence of dash cameras in the market, there is a major slack in the established technology. Most road users nowadays installed an on-board camera in their vehicles for their own personal safety measures of road monitoring. Apparently, with high resolutions of camera that achieve up to 2560 x 1440 (4K) in certain model, lack of intelligent system is a major loss. Intelligent system such as vehicle detection, vehicle classification and vehicle speed estimations are underappreciated to be taken advantage to be part on the dash camera feature specifications.

Nevertheless, image processing techniques implemented on the development on either the three systems; vehicle detection, classification and speed estimation, exist in a contribution for road monitoring purposes. However, the development only focuses on the implementation using static surveillance cameras (CCTVs) as the main input. Disadvantage point from using static cameras is that it limits the location and area for monitoring a large scale data information extraction (Wang, 2013).

Speed estimation system often integrated with the use of Radar technology. On the contrary, the use of Radar associates with high cost equipment sensor (Peng et al., 2015) while in image processing, the availability of cameras with high resolutions can be obtained easily at a cheaper cost. Other than that, the disadvantage of using Radar is that it only covers and measures a single vehicle speed at a time in contrast with the image processing technique that can track more than one vehicle at the same time.

1.3 Objectives of Research

Throughout this research, the main focus was to utilize dynamic road scenes recorded by the on-board camera installed in host vehicles. Hence the overall goal was to develop algorithms that can analyse the information available on the video sequences. Therefore, this research embarked on the following objectives:

i. To develop an algorithm of vehicle detection and classification based on dynamic video footages using Haar-Like features with Cascade classifier and ratio property vehicle classification.
ii. To develop an algorithm of speed estimation classification based on dynamic video footages using scale factor and centroid measurement.
iii. To analyse and validate the developed algorithms using video database recorded by the host vehicles using on-board cameras.

1.4 Scope of Research

The research focused on developing an algorithm for vehicle field related course of vehicle detection, vehicle classification and vehicle speed estimation using image processing techniques. Details on the scope of work were categorised into two sections namely data preparations and algorithm development.

1.4.1 Data Preparations

For this research, there were no standard databases available to contribute in the algorithm development. Despite of the limitations, a new image dataset and video database for this research were created with the criteria as described below:

i. The video sequences were recorded using on-board cameras installed in vehicles and located at the dashboard area of the host vehicles producing road scenes in dynamic where the foreground (vehicle) and background were in motions.

ii. The highway scenes were recorded from Ayer Keroh, Melaka to Skudai, Johor for two-lane highways, and from Ayer Keroh, Melaka to Kajang, Selangor for three-lane highways.

iii. The back-view profile of the vehicles has been set as the main feature since the videos were recorded in a forward motion based on drivers' point of view of the host cars on the road.

iv. The collection of positive image dataset comprised four types of vehicles; car, lorry, bus, and motorcycle.

1.4.2 Algorithm Development

Details on the software tools, performance measurement and algorithm method focus, used in this research development were as described below:

i. Matlab Software was the main platform for algorithm development started from the preparations of data until the performance measurements.