

# FORWARD COLLISION WARNING SYSTEM USING CASCADE CLASSIFIER ON EMBEDDED PLATFORM

BY

MUHAMMAD ASYRAF BIN ZULKHAIRI

A dissertation submitted in fulfilment of the requirement  
for the degree of Master of Science (Mechatronics  
Engineering)

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International Islamic University Malaysia

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## ABSTRACT

Every year, about 1.3 million people died on road traffic worldwide. Road traffic death number continues to increase steadily over years and reached 1.35 million in 2016. Road traffic injuries have become the leading killer or cause of death for children and young adults with range of age between 5-29 years old (WHO, 2018). Thus, traffic accident problem is crucial and need to be improved. Advanced Driver-Assistance Systems (ADAS) help reducing traffic accidents caused by distracted driving. One of the features of ADAS is Forward Collision Warning System (FCWS). In FCWS, car detection is a crucial step. This project explains about car detection system using cascade classifier running on embedded platform with single camera as the only sensor. Developing a system that use single camera to detect a car and predict its distance is quite a challenging task. Thus, a good image processing algorithm is needed to perform such task. The embedded platform used is NXP SBC-S32V234 evaluation board with 64-bit Quad ARM Cortex-A53. The system algorithm is developed in C++ programming language and used open source computer vision library, OpenCV. For car detection process, object detection by cascade classifier method is used. The cascade detector is trained using positive and negative instances mostly from our self-collected Malaysian road dataset. 4564 positive images have been used to train a car detector which turns out to be enough to produce acceptable results. A distance estimation method is used, and the developed system can give warning based on distance and Time to Crash (TTC). The distance estimation algorithm can produce acceptable results with maximum deviation percentage of 3.88875 %. In term of performance, when running on embedded platform, the FCWS runs at average of 9.52 FPS when scanning default ROI and at average of 16.86 FPS when tracking a car.

## خلاصة البحث

في كل عام، يموت حوالي ١,٣ مليون شخص في حركة المرور على الطرق حول العالم. يستمر عدد الوفيات الناجمة عن حوادث الطرق في الازدياد على مر السنين ووصل إلى ١,٣٥ مليون في عام ٢٠١٦. حيث أصبحت إصابات حوادث الطرق هي القاتل الرئيسي أو سبب الوفاة للأطفال والشباب الذين تتراوح أعمارهم بين 5-29 سنة (WHO, 2018). وبالتالي، فإن مشكلة الحوادث المرورية حاسمة ويجب تحسينها. تساعد أنظمة مساعدة السائق المتقدمة (ADAS). في الحد من حوادث المرور الناتجة عن تشتيت القيادة. واحدة من ميزات ADAS هي نظام التحذير من الاصطدام الأمامي (FCWS). يعد اكتشاف السيارة خطوة أساسية في FCWS. هذا المشروع يشرح نظام الكشف عن السيارة باستخدام مصنع Cascade الذي يعمل على منصة مدججة مع كاميرا واحدة كمستشعر وحيد. ويعد تطوير هذا النظام الذي يستخدم كاميرا واحدة لاكتشاف السيارة والتنبؤ بمسافتها وهي مهمة صعبة للغاية. وبالتالي، هناك حاجة إلى خوارزمية جيدة لمعالجة الصور لأداء مثل هذه المهمة. ولقد المنصة المدججة المستخدمة هي لوحة التقييم NXP SBC-S32V234 مع Quad ARM Cortex-A53 64bit. لقد تم تطوير خوارزمية النظام بلغة البرمجة ++C واستخدام مكتبة رؤية الآلة مفتوحة المصدر، OpenCV. بالنسبة لعملية الكشف عن السيارات، يتم استخدام الكشف عن الأشياء بطريقة التصنيف Cascade. ومن تم تدريب الكاشف باستخدام النماذج الإيجابية والسلبية من مجموعة بيانات تم جمع أغلبها ذاتياً من الشوارع الماليزية. تم استخدام ٤٥٦٤ صورة إيجابية لتدريب كاشف السيارات والذي اتضح أنها كافية لتحقيق نتائج مقبولة. كذلك يتم استخدام طريقة تقدير المسافة، ويمكن للنظام المطور إعطاء تحذير بناءً على المسافة ووقت الاصطدام (TTC). ويمكن أن تنتج خوارزمية تقدير المسافة نتائج مقبولة مع نسبة انحراف قصوى تبلغ ٣,٨٨٨٧٥٪. من حيث الأداء، عند تشغيله على النظام المدمج، ويعمل FCWS بمتوسط ٩,٥٢ إطاراً في الثانية عند مسح منطقة الاهتمام وبمعدل ١٦,٨٦ إطاراً في الثانية عند تتبع السيارة.

## APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science (Mechatronics Engineering).

.....  
Yasir Mohd Mustafah  
Supervisor

.....  
Zulkifli Zainal Abidin  
Co-Supervisor

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science (Mechatronics Engineering).

.....  
Muhammad Mahbubur Rashid  
Internal Examiner

.....  
Ahmad Imran Ibrahim  
Internal Examiner

This dissertation was submitted to the Department of Mechatronics Engineering and is accepted as a fulfilment of the requirement for the degree of Master of Science (Mechatronics Engineering).

.....  
Syamsul Bahrin Abdul Hamid  
Head, Department of  
Mechatronics Engineering

This dissertation was submitted to the Kulliyah of Engineering and is accepted as a fulfilment of the requirement for the degree of Master of Science (Mechatronics Engineering).

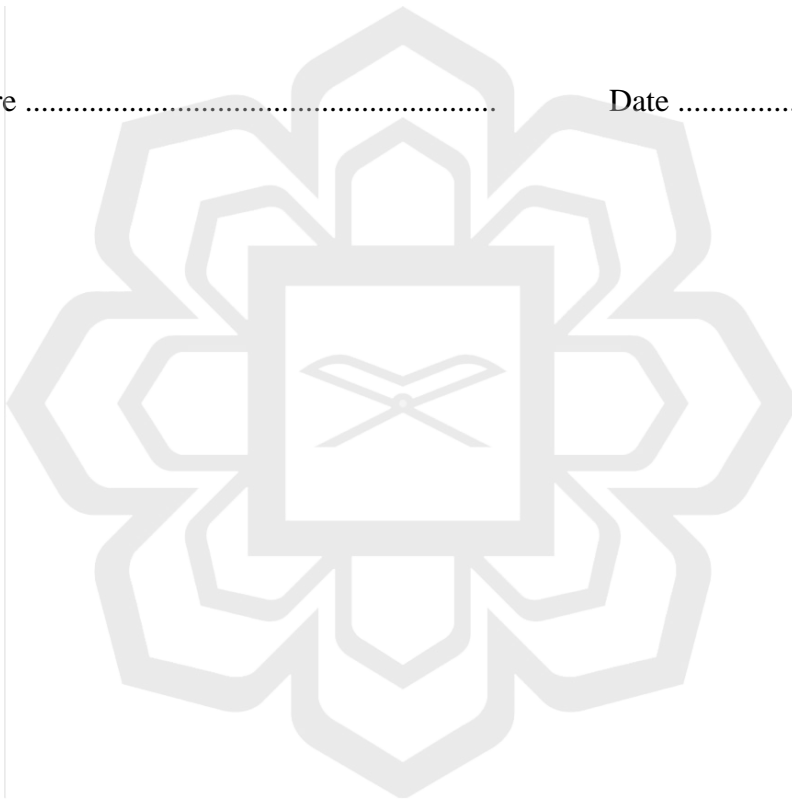
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## DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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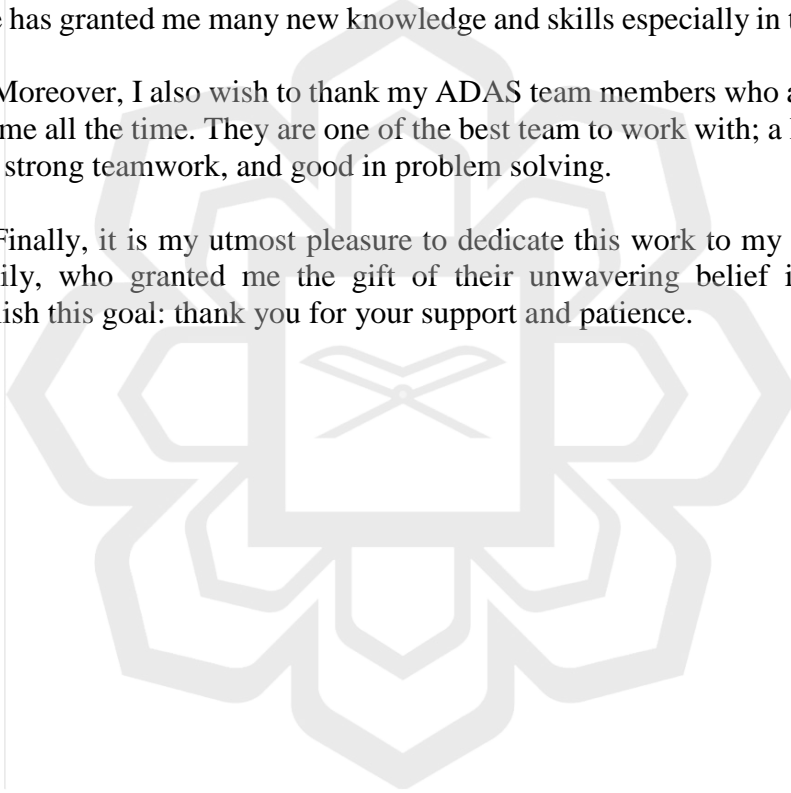
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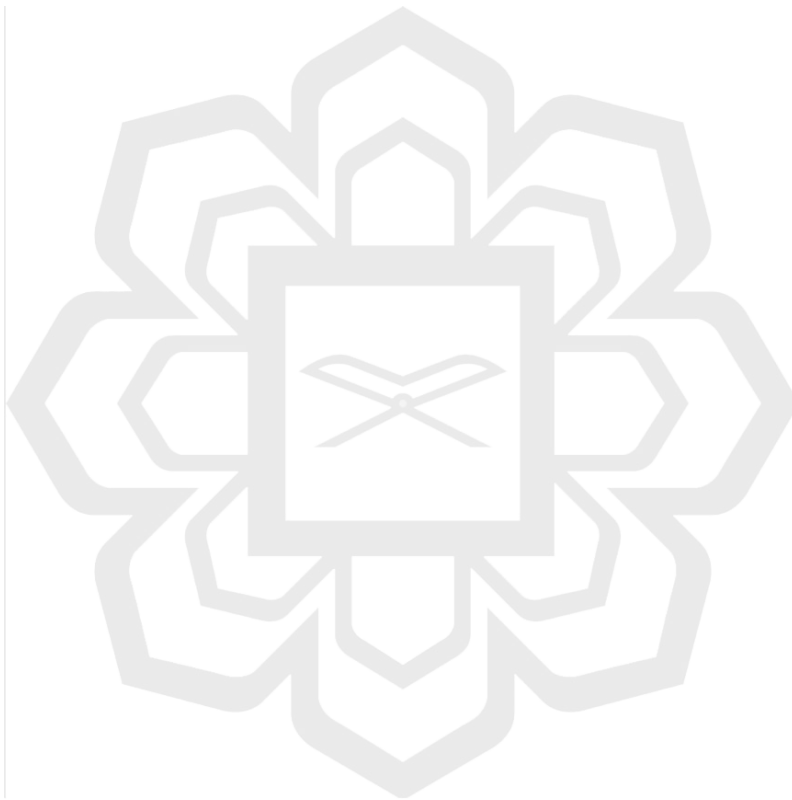
Finally, it is my utmost pleasure to dedicate this work to my dear parents and my family, who granted me the gift of their unwavering belief in my ability to accomplish this goal: thank you for your support and patience.



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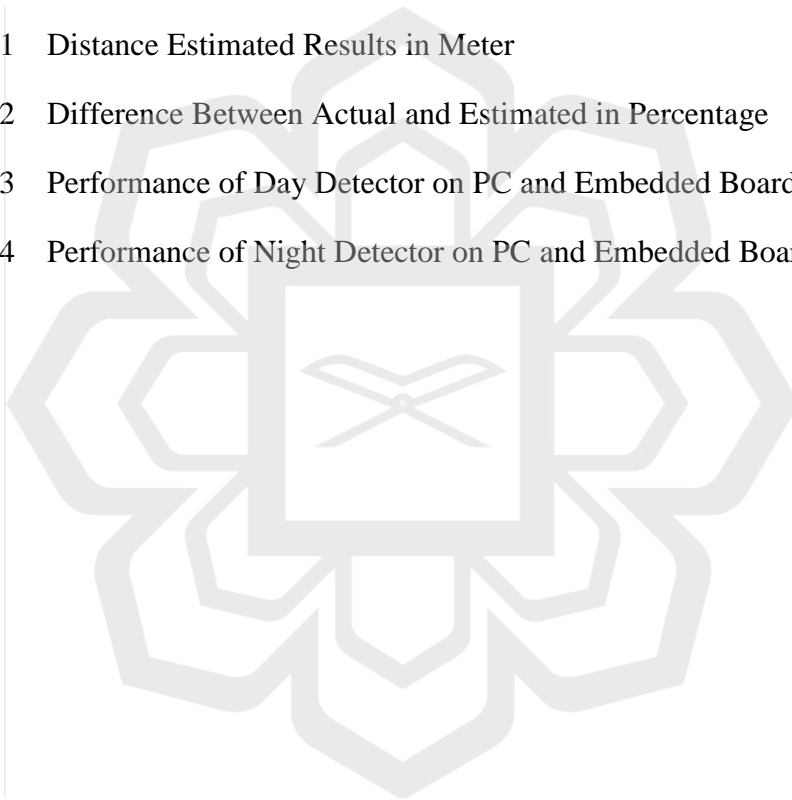
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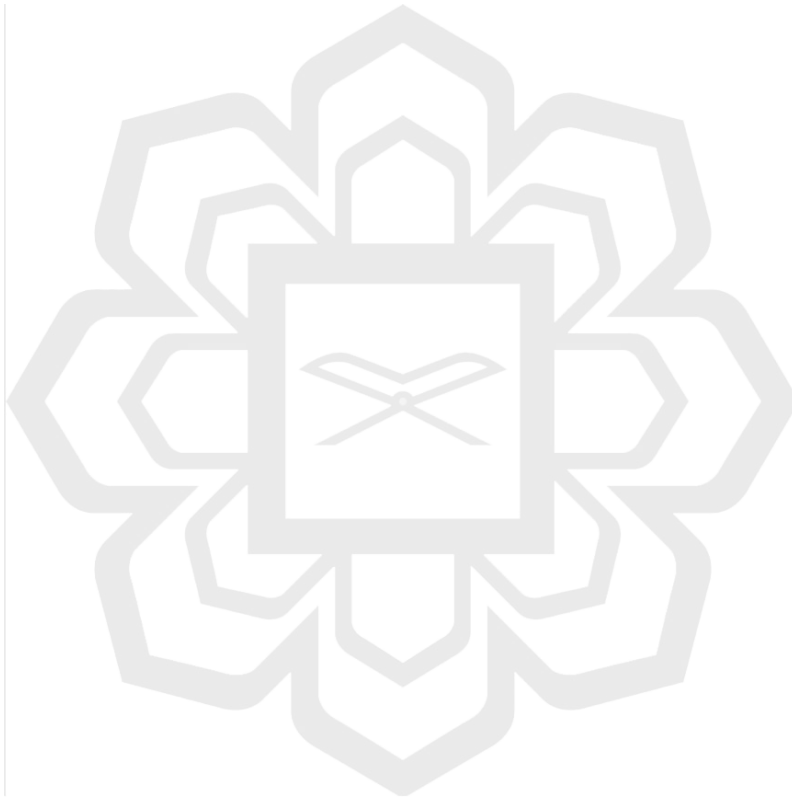


## LIST OF ABBREVIATIONS

ADAS	Advanced Driver Assistance System
FCW	Forward Collision Warning
FCWS	Forward Collision Warning System
FPS	Frames Per Second
GUI	Graphical User Interface
HOG	Histogram of Oriented Gradient
IDE	Integrated Development Environment
LBP	Local Binary Pattern
LDWS	Lane Departure Warning System
OpenCV	Open Computer Vision
OS	Operating System
PC	Personal Computer
ROI	Region of Interest
TTC	Time to Crash

## LIST OF SYMBOLS

%	Percent
s	Second
m	Meter
ms	Millisecond



# CHAPTER ONE

## INTRODUCTION

### 1.1 OVERVIEW

Every year, about 1.3 million people died on road traffic worldwide. Road traffic death number continues to increase steadily over years and reached 1.35 million in 2016 (WHO, 2018). Road traffic injuries have become the leading killer or cause of death for children and young adults with range of age between 5-29 years old (WHO, 2018). Technologies have help humans improving the health care by preventing some diseases for instance, but in the same time have created another challenge that needed to be solved. Traffic accident problem is crucial and requires attention from all in order to solve it as soon as possible.

There are several ways to improve road traffic safety and they can be categorized into three phases which are the pre-event phase, at the event phase and the post-event phase (Haddon & Background, 1968) as cited by (Goniewicz et al., 2016). It is worth to focus on the pre-event phase which will more likely contribute to reduction of road accidents. For pre-event phase, there are many ways to prevent road accidents. One of the ways is by improving the road traffic safety policy to cover wider range of participants from various group such state, research institutes, fire rescue services, medical, police, industry, media and road users. More participants' engagement can lead to new methods development thus improving road traffic safety system. Nonetheless, a good education covering the road traffic safety area is also able to minimize mistakes made by road traffic user. The modes of education can be like educational programmes, promotion campaign, older driver's improvement courses and media campaign. Apart

from that, legislation also may be able to reduce risky behavior among road traffic users thus improving road traffic safety. Among road traffic laws examples are speed limit in areas with high population density, alcohol level control among road traffic users, obligation on using protective helmet for motorcyclist, obligation on using safety seatbelts and obligation on using child car seats. Moreover, new technologies development results in designing safer cars which have passive or active car safety systems and implementing many safety systems relating the road infrastructure. Technologies advancement also has enabled officer to easily penalize road traffic users who violate the rules with help from various systems such as speed camera and sensors detecting cars that run red light which contribute to reduction of errors made by road users according to (World Health Organization, 2013) as cited by (Goniewicz et al., 2016).

Among new technologies that are currently developed is autonomous car. Autonomous car is very promising in reducing car accident fatalities. However, a full autonomous car is still under development and when the development is complete, it will take some time to penetrate into the market and available to average consumer. Moreover, note that developing a fully autonomous car that can drive around in a crowded traffic with unpredictable maneuvers of human drivers is very challenging. In consequence of that, fully autonomous cars are still far in the future, but cars equipped with Advanced Driver Assistance System (ADAS) is slowly getting into the market. However, for this moment, commercial cars that support ADAS feature are very expensive and they are considered as luxury items. Thus, the aim of this project is to develop a cost-effective Forward Collision Warning System (FCWS) for car that use monocular camera which is less expensive. FCWS is one of the main features of an ADAS system. FCWS able to give an alert to the driver if there is a possible frontal

collision with a car in front. Detecting a car in front with input from sensors like radar and LIDAR is not too difficult but with input from camera only, it is quite a challenging task. It is also worthy to note that image processing needs more computational power compared to radar.

## **1.2 PROBLEM STATEMENT**

The number of cars on the road increases over years so does the number of car accident cases. Among the causes of car accidents is due to human error such as sleepiness, distracted by mobile phone, and others. In fact, human error might be the major causes of car accident cases. Road traffic accident can cause temporary injury, permanent injury and even death which highlights the importance of developing ways to reduce car accident cases. One of the ways to reduce car accident is by installing an Advanced Driver Assistance System (ADAS) in a car. One of the features of ADAS is Front Collision Warning System (FCWS).

The increasing number of cars also reducing the traffic efficiency. Humans who act as car drivers are unique; every human has different ways of driving thus each driver is not following certain standard. Humans also are unpredictable, and some make mistakes on the road since they have a choice to follow the traffic rules or not which is in contrast with machines. Thus, one of the ways to increase the traffic efficiency is by implementing autonomous driving vehicles. One of the crucial tasks in an autonomous car is FCWS.

There are several ways to detect vehicle ahead such as using radar, Lidar, and depth sensor (dual camera) and camera. However, camera is the most cost-effective sensor if the range of distance is considered since long-range radar or Lidar are more expensive. In addition to that, only luxury cars are normally shipped with ADAS. Most

of the cars available in the market are not shipped with FCWS and users need to install FCWS as accessories if they want this safety feature. In term of installation cost as an accessory, FCWS that use camera is the lowest since it is easier to install; only need to install on the windshield which can be self-installed by customer. Thus, using camera as sensor to detect car is preferred because it is easier to install as an accessory and cost-effective to cover longer distance.

Although vision-based FCWS has been researched many times before and some FCWS products are already available in the market, the topic is still being developed and there are several things such as object detection speed, object tracking algorithm, and object detection method which need to be optimized indicating that it is far from perfect. The purpose of this project is to study various ways to improve FCWS by trying to get acceptable FPS and acceptable detection accuracy. There are countless ways in image processing that can be implemented to achieve certain task and every method has their own advantages and disadvantages. This project aims to design a FCWS that is cheap but able to produce acceptable results.

### **1.3 RESEARCH OBJECTIVES**

The objectives for this research are:

- 1- To analyze and train object detector using cascade classifier to perform car detection task for FCWS.
- 2- To develop a single camera Forward Collision Warning System (FCWS) running on embedded platform.
- 3- To test the developed system and evaluate its performance in real-time with different environment.

## 1.4 RESEARCH METHODOLOGY

The section will explain the technique, tools, parameters and benchmark used for this project. There are several research techniques such as experimental, simulation and theoretical. This project is an image processing project which requires a lot of software development. The hardware development only consists of setting up a camera, embedded board, and a screen to display output. Two same setups have been built; one is indoor and one on a test car. The FCWS algorithm is developed stages by stages and involve a lot of testing and experiment. Thus, it can be concluded that the technique used for this project is experimental.

There are several tools used for this project and one of them is MATLAB which is used to train the cascade classifier detector. The advantage of using MATLAB is that it is easier to use since the MATLAB programming language is high level which require less lines of code and it has a big community which results in better development support. Besides, the tool used to label the dataset is an open source software called LabelImg which is available online at GitHub (tzutalin, 2015). This software is popular in object detection development. The advantage of using an open source software is that it is free of charge. Moreover, a laptop with Ubuntu 16.04 OS is used to develop the algorithm. The IDEs used to develop the program are Eclipse and S32 Design Studio which is provided by the company that make the embedded board that is used for this project. The Eclipse is used to test the algorithm running on computer and the S32 Design Studio is used to test the algorithm running on embedded.

The following methodology is used to achieve the objectives of the project.

1. *Literature review on Forward Collision Warning System projects and its development.* Research is performed by gathering information from various sources such as conference paper and online articles.

2. *Train and analyze different cascade classifier detectors for car detection.*

This is done to test the performance of different detectors for car detection and finally choose one for FCWS application.

3. *Design and development of FCWS algorithm.* Other than car detection algorithm, other algorithms are added to increase performance and efficiency of the system.

4. *Evaluate the system performance in a simulated environment.* The system will be evaluated in a simulated environment and then depends on the results, debugging and tuning will be applied.

5. *Evaluate the system performance on embedded platform and on car setup.* The system will be evaluated on embedded platform and then depends on the results, debugging and tuning will be applied.

Basically, there are two main developments; cascade classifier detectors (car detector) training and FCWS algorithm development. For FCWS algorithm development, a feature or algorithm is added, tested, and tuned before adding another feature. Figure 1.1 shows the overall flow of the project in chart to help better understanding of the overall process.

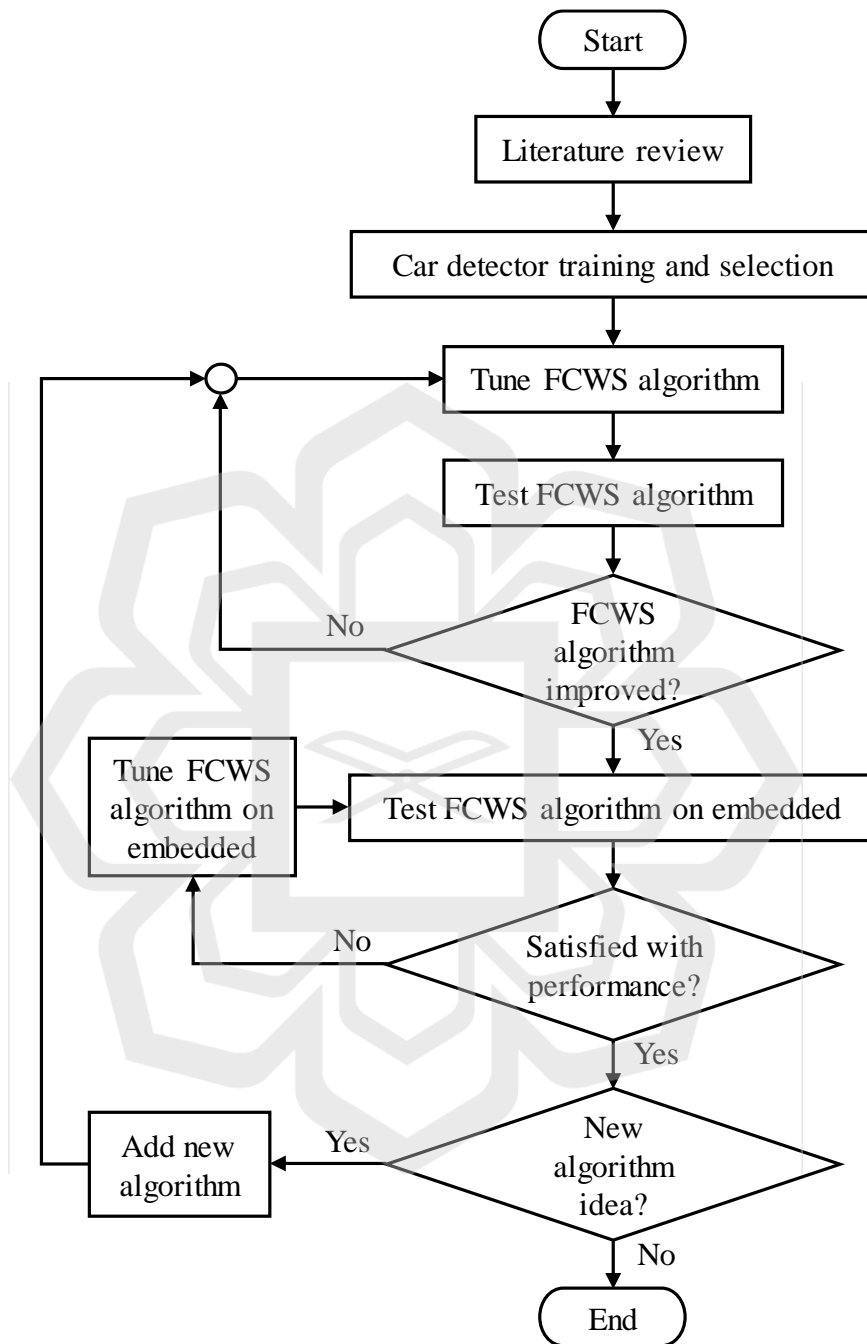


Figure 1.1 Flowchart of the Project

## 1.5 RESEARCH SCOPE

Several sensors can be used to develop FCWS such as radar, ultrasonic sensor, Lidar, and camera. This project uses camera only for car detection. There are many types of camera used in FCWS, however this project will only be focusing on monocular camera images. The monocular camera is much cheaper than stereo camera thus with a monocular camera-based system, the cost of a FCWS can be reduced.

Moreover, the FCWS for this project is aimed to detect the back of a car only since the labelled datasets consist of back of cars only. Side of a car and front of a car are not guaranteed to be detected by the developed system. Detecting back of a car is crucial since forward collision typically occur with back of a car.

In addition, this project focus on detecting car images that are captured through egocentric vision of a vehicle only. Thus, it is not applicable to detect cars through traffic monitoring camera and etcetera. The camera used for the developed FCWS is located at the center of a car windscreen thus, the system is not guaranteed to work well for different camera viewing angle.

The developed FCWS for this project is aimed to work well for average consumer cars and average drivers only. For high end cars like sport cars that able to take corners in high speed, the developed system may not work well. Moreover, the system can only detect fully visible cars; cars with some occluded parts will not be detected. Thus, the system will not detect cars in front that is too close with the ADAS car.

Moreover, the developed FCWS is tested for day and night only. Other weather condition such as raining, storm, snow, haze, and foggy is not tested. Since the dataset used to train the car detector consist of day and night environment only, the detection is not expected to perform well in other environment.

Finally, the project focused on developing the software part of FCWS. The hardware used for this project are an embedded board, a camera, and a display screen. The hardware part is not complete since for final product setup, a buzzer to provide audio warning is needed and the display screen will be removed. The display screen is just for development purposes.

## **1.6 REPORT ORGANIZATION**

This research report is divided into several chapters.

### **Chapter 1: Introduction**

This chapter discusses about the project overview which consists of problem statements, research objectives, and research methodology.

### **Chapter 2: Literature Review**

This chapter reviews several literatures about autonomous car technology, image processing, object detection, FCWS projects, and FCWS development.

### **Chapter 3: System Design**

This chapter discusses the design of the FCW system and the development process. Moreover, this chapter also explains on how the car detector were trained using cascade classifier method.

### **Chapter 4: Results and Discussion**

This chapter presents the experimental results of algorithm test, distance accuracy test and FCWS performance test.

## **Chapter 5: Conclusion and Recommendation**

This chapter summarizes the works that have been done for this project. Moreover, this chapter also suggests some recommendations for future work of this project.

