MOTION ESTIMATION FOR 1-CHANNEL AROUND VIEW MONITORING IN ADVANCE DRIVER ASSISTANCE SYSTEM USING WIDE FISHEYE CAMERA

BY

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

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MARCH 2022

ABSTRACT

Around View Monitoring (AVM) system uses multiple input cameras mounted on different vehicle positions to display 360° bird-eye-view around the vehicle that is not readily visible to the driver. The development of this system will reduce parking accidents by monitoring its surroundings, detecting lanes, and identifying obstacles. Even a short propel guidance can diminish the number of accidents, even minor ones. This project proposes developing one ultra-wide-angle camera on the rear vehicle integrated with the motion estimation (ME) algorithm to produce a parking bird-eye view. This algorithm will not depend on other sensors such as GPS, odometer, and steering. The AVM system must be fast enough to make the image as a bird's eye view and make it as close as possible compared to the real world. The algorithm will use information from ME to stitch image sequences captured from the front or rear of vehicles. Hence, it will create a synthetic image around the vehicle for the AVM system. With this solution, all kinds of vehicles will have AVM technology, even the old vehicles. Before applying ME in the AVM algorithm, the images will undergo pre-processing, which are dewarping, top-down view, and cropped. ME is needed to calculate vectors that show the motion of the vehicle. The studies show that the ME method that can be used for a homogeneous surface is indirect. From the indirect method, there are optical flow and block matching. After the analysis, optical flow is deemed unsuitable for a real-time ADAS system as it fails at least 25.5% of the time. This statistic means, out of 100 frames, the algorithm will fail at least for 25 frames. Usually, the real-time application is up to 30 frames per second. 25 frames are close to one second, and an error of one second is unacceptable. On the other hand, for block matching, the results for percentage fails are 6.76% and 18.24% for left and right segments of the images. The ME methods result are analyzed, and the block matching method fits the system with the highest accuracy and lowest processing time. Thus, the new algorithm for the AVM system is based on the Block Matching method. This project's algorithm is on par with CCORR_NORMED with 14.86% and 18.98% fail percentages for left and right segments, respectively. CCORR_NORMED processing speed is 4.323ms, while this project's ME is 4.655ms. PC platform produces 12.750 ms processing speed with 47 fps, 94.594 ms with 10 fps on Renesas, and 172.955 ms with 5 fps on Telechips.

خلاصة البحث

يستخدم نظام مراقبة الرؤية المحيطة (AVM) كاميرات إدخال متعددة مثبتة على مواضع مختلفة للسيارة لعرض رؤية عين الطائر بزاوية 360 درجة حول السيارة والتي لا يمكن رؤيتها بسهولة للسائق. سيؤدي تطوير هذا النظام إلى تقليل حوادث وقوف السيارات من خلال مراقبة محيطه ، واكتشاف الممرات ، وتحديد العقبات. حتى التوجيه القصير للدفع يمكن أن يقلل من عدد الحوادث ، حتى الحوادث الصغيرة. يقترح هذا المشروع تطوير كاميرا واحدة فائقة الزاوية على السيارة الخلفية مدمجة مع خوارزمية تقدير الحركة (ME) لإنتاج عرض عين طائر وقوف السيارات. لن تعتمد هذه الخوارزمية على أجهزة استشعار أخرى مثل GPS وعداد المسافات والتوجيه. يجب أن يكون نظام AVM سريعًا بما يكفي لجعل الصورة كمنظر عين الطائر وجعلها قريبة قدر الإمكان مقارنة بالعالم الحقيقي. ستستخدم الخوارزمية معلومات من ME لغرز تسلسل الصور الملتقطة من مقدمة أو خلف المركبات. وبالتالي ، ستنشئ صورة اصطناعية حول السيارة لنظام AVM. مع هذا الحل ، ستحتوي جميع أنواع المركبات على تقنية AVM ، حتى المركبات القديمة. قبل تطبيق ME في خوارزمية AVM ، ستخضع الصور للمعالجة المسبقة ، والتي يتم إزالتها ، وعرضها من أعلى لأسفل ، وقطعها. هناك حاجة إلى ME لحساب المتجهات التي تظهر حركة السيارة. تظهر الدراسات أن طريقة ME التي يمكن استخدامها لسطح متجانس غير مباشرة. من الطريقة غير المباشرة ، هناك تدفق بصري ومطابقة كتلة. بعد التحليل ، يعتبر التدفق البصري غير مناسب لنظام ADAS في الوقت الحقيقي لأنه يفشل على الأقل 25.5٪ من الوقت. تعني هذه الإحصائيات ، من بين 100 إطار ، ستفشل الخوارزمية على الأقل لـ 25 إطارًا. عادة ، يصل التطبيق في الوقت الفعلي إلى 30 إطارًا في الثانية. 25 إطارًا قريبة من ثانية واحدة ، وخطأ لمدة ثانية واحدة غير مقبول. من ناحية أخرى ، بالنسبة لمطابقة الكتلة ، فإن نتائج النسبة المئوية للفشل هي 6.76٪ و 18.24٪ للمقاطع اليسرى واليمنى من الصور. يتم تحليل نتيجة طرق ME ، وتناسب طريقة مطابقة الكتلة النظام بأعلى دقة وأقل وقت معالجة. وبالتالي ، تعتمد الخوارزمية الجديدة لنظام AVM على طريقة مطابقة الكتلة. خوارزمية هذا المشروع على قدم المساواة مع CCORR_NORMED بنسبة 14.86٪ و 18.98٪ من حالات الفشل للقطاعين الأيسر والأيمن ، على التوالي. تبلغ سرعة معالجة CCORR_NORMED 4.323 مللي ثانية ، بينما تبلغ سرعة هذا المشروع 4.655 مللي ثانية. تنتج منصة الكمبيوتر 12.750 مللي ثانية من المعالجة بـ 47 إطارًا في الثانية و 94.594 مللي ثانية مع 10 إطارات في الثانية على Renesas و 172.955 مللي ثانية مع 5 إطارات في الثانية على Telechips.

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 thesis for the degree of Master of Science (Mechatronics Engineering).

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DECLARATION

I hereby declare that this thesis results from my investigations, except 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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ACKNOWLEDGEMENTS

IN THE NAME OF ALLAH, THE MOST COMPASSIONATE AND THE MOST MERCIFUL

I thank Allah S.W.T, Sustainer and the Creator of the universe and its inhabitant, for He has given me HIS blessings and making it possible for me to complete this thesis.

Firstly, 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.

I wish to express my appreciation and thanks to those who provided their time, effort, and support for this project. To the dissertation committee members, thank you for sticking with me.

Finally, a special thanks to Associate Professor Nik Nur Wahidah for his continuous support, encouragement, and leadership, and for that, I will be forever grateful.

This research is supported by International Islamic University Malaysia (IIUM) with Collaborative Research in Engineering, Science & Technology Center (CREST) and Delloyd R&D (M) Sdn. Bhd. (Project ID P11C2-17 & SP17-029-0291)

This thesis is dedicated to my late father and my mother for laying the foundation of what I turned out to be in life.

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LIST OF ABBREVIATIONS

AVM	Around View Monitoring
GPU	Graphical Processing Unit
IMU	Internal Measurement Unit
ME	Motion Estimation
OS	Operating System
PC	Personal Computer
RAM	Random Access Memory
RGB	Red-Green-Blue
ROI	Region of Interest

LIST OF SYMBOLS

K	Camera Matrix
D	Distortion Coefficient
x_i	Len's Shape Parameter
a	width (mm)
b	height (mm)

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Transportation is one of the most critical aspects of human civilization. People will use the transportation system every day, especially to work and during emergency events. Therefore, it is essential to ensure the safety of the passengers and drivers while they are using the transportation system. An advanced driver assistance system (ADAS) is a new technology currently being studied and developed focusing on the safety of drivers and passengers in the vehicle. An around view monitoring (AVM) system is one of the features designed under the ADAS spectrum, as illustrated in Figure 1.1. It is a system that can produce a top view of the vehicle's surrounding for the driver's view. At the same time, motion estimation (ME) is a technique that can be used in AVM image processing. The development of AVM will undoubtedly contribute to the increase of safety measures for road users using any transportation.

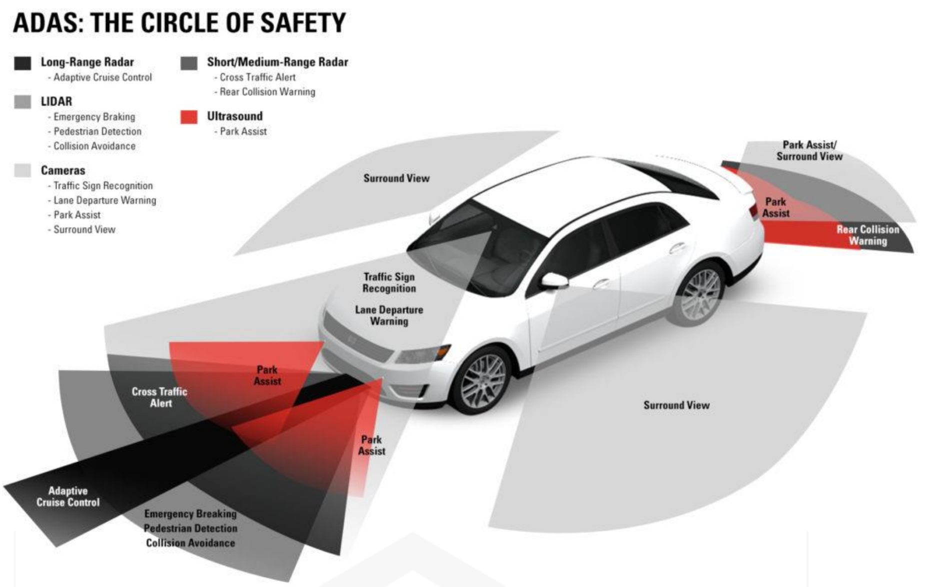

Figure 1.1 Overall features of ADAS (*ADAS: Features of Advanced Driver Assistance Systems*, n.d.)

As shown in Figure 1.1, AVM is one of the ADAS features using a camera. It is shown in light gray color and written as surround view. The commercial vehicle usually uses four cameras positioned outside the car; center at the front, under both side mirrors, and center at the rear, as indicated by red arrows in Figure 1.2. Some of them also use ultrasonic sensors to detect objects surrounding the car. Figure 1.2 also shows the example of the AVM final product.

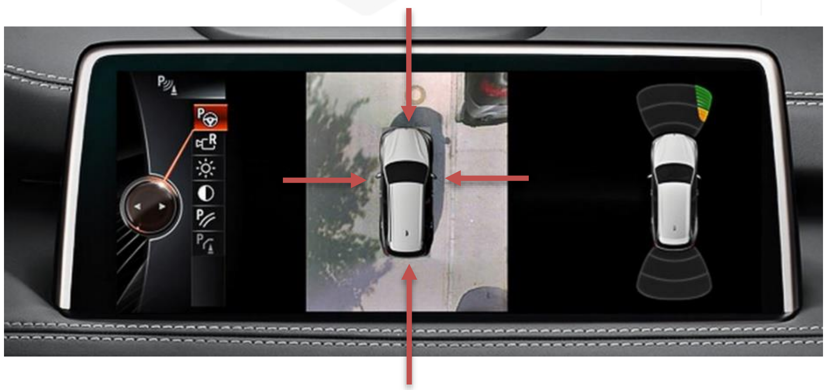

Figure 1.2 Example of Around View Monitoring from BMW (*What Are Car Surround View Cameras, and Why Are They Better than They Need to Be? - ExtremeTech*, n.d.)

Motion estimation (ME) is a process to find the same pixel size between frames to determine the motion vector. Motion is the crucial source of information in video sequences. Sequential frames may contain the same object, but the object is either still at the same place or moved to a new location due to the object's moving in the real world or camera motion. ME is primarily designed for video compression to make the output more stable. According to (Pesquet-popescu et al., n.d.-a), ME is essential for computer vision, image sequence analysis, and video communication. Therefore, it needs to be accurate and efficient.

In the real world, motion can be complicated. It may be a combination of rotation and translation, which will be challenging to estimate the motion, thus requiring high processing. However, in sequential frames, the motion can only be translated as the gap between frames is 0.1 seconds for ten frames per second (fps) or 0.033 seconds for 30 fps video. The interval between two frames is small so that motion can be estimated and used effectively for further processing, such as motion compensation.

According to (Pesquet-popescu et al., n.d.-b), there are several approaches for ME. These approaches are optical flow, pel-recursive, transform-domain, block matching, parametric ME, and multi-resolution methods. Among all these approaches, block matching algorithms (BMA) have been used the most due to their efficiency and simplicity, as claimed by (Baraskar et al., 2015). ME can be classified as shown in Figure 1.3.

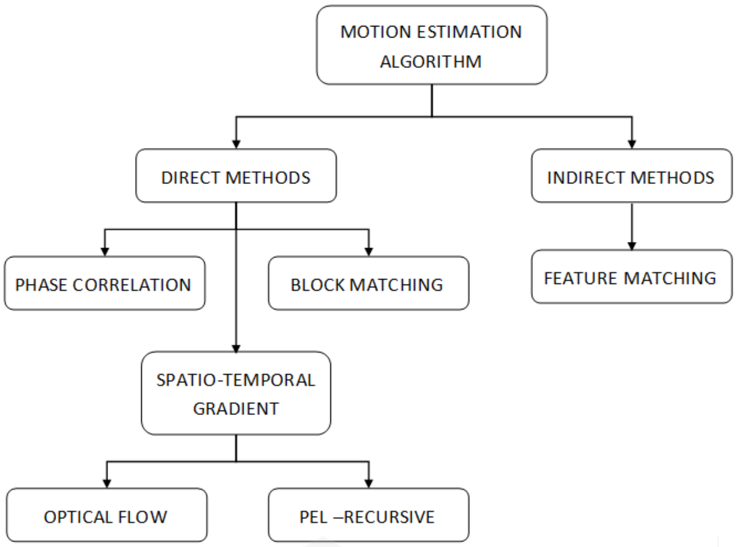

Figure 1.3 Classification of Motion Estimation

1.2 PROBLEM STATEMENT

In 2019 alone, there are 567,516 traffic/road accidents, which put Malaysia in the top rank of the road accident relative to its population (*Portal Rasmi Kementerian Pengangkutan Malaysia Kemalangan Dan Kematian Jalan Raya Di Malaysia*, n.d.). The accident rate has increased from 2010 to 2019, as shown in Figure 1.4. This statistic includes all the fender benders maneuvering in narrow spaces and parking spaces.

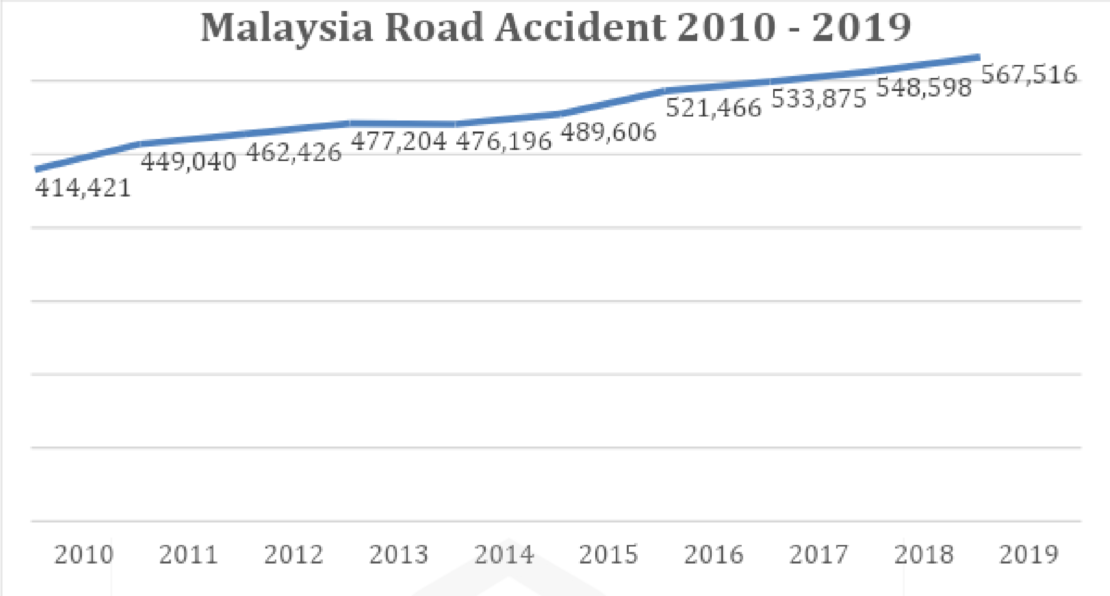

Figure 1.4 Malaysia Road Accident 2010 – 2019 (*Portal Rasmi Kementerian Pengangkutan Malaysia Kemalangan Dan Kematian Jalan Raya di Malaysia*, n.d.)

A technology called Around View Monitoring (AVM) is currently being developed to assist drivers during parking and maneuvering in tight spaces to reduce the number of casualties from accidents. AVM requires an accurate and efficient real-time bird's eye view with forward/backward trajectory lines. Current AVM uses parameters information from the odometer, a global positioning system (GPS), and a steering system to calculate the trajectory lines. Conventionally, there are two types of AVM systems:

1. Four-channel AVM system (using four cameras)

2. One-channel AVM system (using one camera)

One-channel AVM system requires fusing with other systems such as the odometer, the global positioning system (GPS), and the steering system to produce the bird's eye view. Each system has its flaws. The odometer and steering system cannot detect a slippage, thus creating a crooked bird's eye view. Moreover, GPS cannot be used when the environment is cloudy and if the GPS is in a tall building. Another problem for AVM system manufacturers is that manufacturers for the odometer, GPS, and steering system are reluctant to have their systems being tampered with as it will affect their safety. As the AVM system is dependent on other systems, thus failure in any one of the systems may affect the validity and performance of the AVM output.

An after-market AVM system is sold in Malaysia using four cameras. However, fixing an AVM system in a car is expensive. Currently, AVM systems are built-in with the car. Not all vehicles are suitable to use the current AVM system. Furthermore, not all vehicles are currently being sold with the AVM system, thus limiting users' options.

Thus, developing a one-channel AVM system algorithm using ME will significantly contribute to ADAS technology. Because the motion vector between frames is small, ME will be suitable for capturing the motion. Therefore, it can stitch two conservative frames as the difference was insignificant.

This new algorithm will not require information from other systems such as odometer, GPS, and steering system. Thus, the algorithm will not depend on those systems' failures.

1.3 RESEARCH OBJECTIVES

The research aims to achieve the following objectives:

1. To develop a new algorithm for AVM system using a single camera during parking.
2. To implement ME on the AVM system.
3. To evaluate the performance of the ME on the developed AVM system.
4. To validate and compare with other existing systems

1.4 RESEARCH METHODOLOGY

This project aims to use ME techniques on images to estimate the motion of ground vehicles, especially on homogenous surfaces. The research methodology is as described in Figure 1.5.

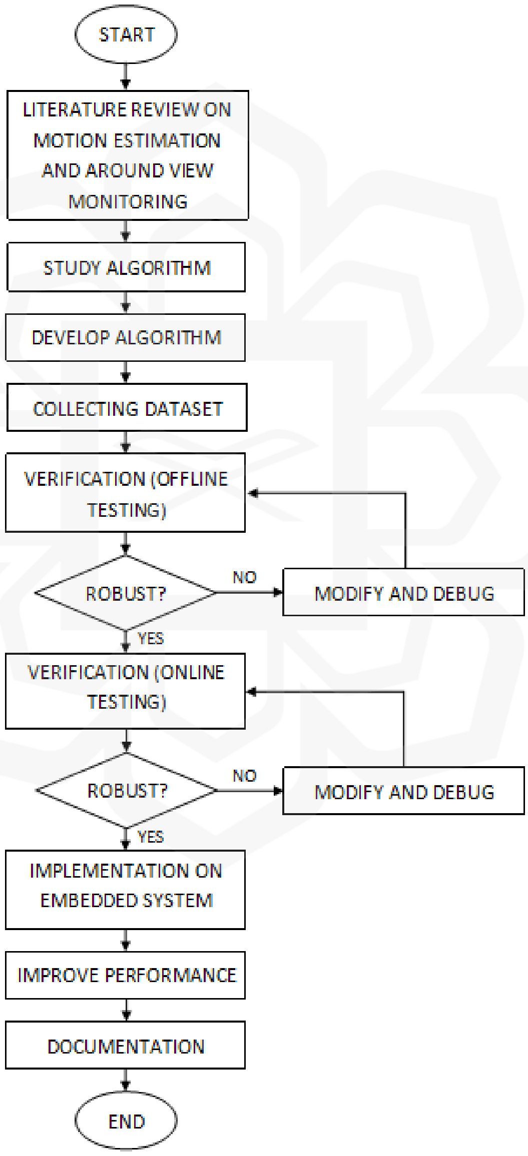

Figure 1.5 Flowchart of research methodology

Based on the flowchart in Figure 1.5, this project's methodology starts with a literature review on Around View Monitoring (AVM) and motion estimation (ME). This step ensures that the project aligns with the current technology and fills the research gap. This project also needs as much information as possible about the industrial demand and their requirements.

The next begins by reproducing results using existing ME algorithms on new videos to identify the best suitable method to achieve the objectives. The ME will be direct or indirect methods, and the selection will be explained in chapter 2. After that, we developed an algorithm for a one-channel AVM system using ME. This process will be presented in the next sub-chapter. At the same time, new datasets were collected to evaluate the performance of the developed algorithm when offline. There are two conditions for the algorithm to be tested: offline and online. Offline testing means the algorithm is tested on a video recorded, while online testing is tested in a real-time environment.

The algorithm must be constantly tested and modified accordingly until the algorithm is robust enough. Next, the algorithm will be tested in real-time. After the algorithm is considered robust during an online test, it will be integrated with an embedded system. The algorithm will require optimization until the embedded system can run in real-time.

1.5 RESEARCH SCOPE

The research focuses mainly on:

i. Developing a one-channel AVM system algorithm using ME uses less computing cost on the embedded system.