



**UNIVERSITI PUTRA MALAYSIA**

***DEVELOPMENT OF 360-DEGREE VIEW IMAGING USING  $L^*a^*b^*$   
COLOR SPACE FOR FRESH FRUIT BUNCH IDENTIFICATION***

**IZAT JARIS BIN DZULKIFLI**

**FK 2021 28**



**DEVELOPMENT OF 360-DEGREE VIEW IMAGING USING  $L^*a^*b^*$   
COLOR SPACE FOR FRESH FRUIT BUNCH IDENTIFICATION**

By

**IZAT JARIS BIN DZULKIFLI**

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

**January 2020**

## **COPYRIGHT**

All material contained within the thesis, including without limitation text, logos, icons, photographs, and all other artwork, is copyright material of Universiti Putra Malaysia unless otherwise stated. Use may be made of any material contained within the thesis for non-commercial purposes from the copyright holder. Commercial use of material may only be made with the express, prior, written permission of Universiti Putra Malaysia.

Copyright © Universiti Putra Malaysia



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

**DEVELOPMENT OF 360-DEGREE VIEW IMAGING USING L\*a\*b\*  
COLOR SPACE FOR FRESH FRUIT BUNCH IDENTIFICATION**

By

**IZAT JARIS BIN DZULKIFLI**

**January 2020**

**Chairman : Muhamad Saufi bin Mohd Kassim, PhD**  
**Faculty : Engineering**

The palm oil industry is well known as a significant agricultural industry in terms of economic benefit for several tropical countries, particularly in Malaysia (Yoshizaki et al., 2013). Total amount of bunches in each of the tree is an important aspect in oil palm harvesting process. In every cycle of harvesting operation, farmer does not have any information on how many bunches and which oil palm tree will be harvested. By introducing 360° view imaging model for bunch identification, number of Fresh Fruit Bunch (FFB) can be identified in a certain plantation area. Black bunch census was done manually to estimate yield. This can be improved by video acquisition using a high-resolution 360° camera integrated with an image processing software for video image processing to get a 360° view of each tree. Based from the standard planting pattern, it is a time consuming process to circle each tree to acquire the 360° view of each tree. In order to overcome this, a new method of data collection was established with the execution of All-Terrain Vehicle (ATV) between rows in the plantation area for video acquisition. The video recorded was processed in a software in order to construct a 360° view of each oil palm tree for further FFB identification process could be done. Image extraction was done using the processing software by referring the data from range sensor installed at the ATV throughout the data collection process in the oil palm plantation. After useful image were extracted, MATLAB software was programmed to process all the selected images for the detection of FFB of each tree. Image pre-processing was conducted where errors in the image were corrected to detect the oil palm bunches. In order to present an appropriate format of image processing system, the RGB images were converted into grayscale images. Image segmentation was done based on a threshold value of L\*a\*b\* to separate between canopy and trunk, fruit bunches and background image. The features were extracted from each pixel of the RGB image. As a result, a new method

for video acquisition is established as well as a processing method for bunch counting for large scale plantation area.

In this research, mean value for  $L^*a^*b^*$  color space was determined by using 90 images samples for image threshold in order to identify the FFB on tree crown. Using  $L^*a^*b^*$  color space, image was threshold to identify black and both red and black FFB. In this research, image verification was done by using the mean  $L^*a^*b^*$  value for black bunch identification. Model threshold verification for 48 samples of images resulted with Coefficient of Determination,  $R^2$  of 0.8029 to identify black bunch on each tree crown. The outcome for this research will help to fully automate the process for bunch identification in the future.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia  
sebagai memenuhi keperluan untuk ijazah Master Sains

**PEMBANGUNAN MODEL IMEJ PANDANGAN 360 DARJAH UNTUK  
MENGENALPASTI TANDAN KELAPA SAWIT MENGGUNAKAN  
RUANG WARNA L\*a\*b\***

Oleh

**IZAT JARIS BIN DZULKIFLI**

Januari 2020

**Pengerusi : Muhamad Saufi bin Mohd Kassim, PhD**  
**Fakulti : Kejuruteraan**

Industri kelapa sawit terkenal sebagai industri pertanian yang signifikan dari segi faedah ekonomi bagi beberapa negara tropika, terutamanya di Malaysia (Yoshizaki et al., 2013). Penuaian kelapa sawit dengan pada masa yang sesuai adalah satu elemen penting; terutamanya jumlah tandan di setiap pokok. Dalam setiap kitaran operasi penuaian, petani tidak mempunyai maklumat tentang bilangan tandan dan pokok kelapa sawit yang akan dituai. Dengan memperkenalkan teknologi baru ini, bilangan Tandan Buah Segar (FFB) boleh dikenalpasti di kawasan perladangan tertentu. Banci buah hitam dilakukan secara manual untuk menganggar hasil. Ini boleh diperbaiki dengan pemerolehan video menggunakan kamera 360° beresolusi tinggi yang dilengkapi dengan perisian pemprosesan imej untuk memproses imej dan video untuk mendapatkan pandangan keliling bagi setiap pokok. Berdasarkan corak penanaman piawai, masa yang diambil untuk mengelilingi setiap pokok untuk memperoleh pandangan 360° setiap pokok agak lama. Untuk mengatasinya, satu kaedah baru diperkenalkan dengan penggunaan ATV di antara baris pokok kelapa sawit di dalam ladang untuk pengambilan video. Video yang dirakam akan diproses dalam perisian untuk mendapatkan pandangan sudut 360° bagi setiap pokok kelapa sawit untuk proses pengenalpastian FFB selanjutnya. Pengekstrakan imej akan dilakukan menggunakan perisian pemprosesan dengan merujuk pada data yang diperolehi daripada sensor jarak yang dipasang di ATV sepanjang proses pengumpulan data di ladang kelapa sawit. Selepas imej berjaya diekstrak, perisian yang diprogramkan akan memproses semua imej yang dipilih untuk mengesan imej setiap tandan pada pokok. Pemprosesan imej dijalankan menggunakan proses penapisan imej untuk mengesan tandan kelapa sawit. Untuk mempersembahkan sistem memperoleh imej yang bagus, imej RGB ditukar menjadi imej skala kelabu. Segmentasi imej dilakukan berdasarkan nilai penapisan untuk memisahkan antara kanopi dan batang, tandan buah dan latar belakang. Ciri-ciri itu diekstrak dari setiap piksel imej

RGB. Sebagai hasil, kaedah baru untuk pengambilalihan video ditubuhkan serta kaedah pemprosesan untuk mengira bilangan tandan untuk kawasan ladang berskala besar mampu dikecapi.

Dalam kajian ini, nilai purata bagi kumpulan warna  $L^*a^*b^*$  telah dikenalpasti untuk menapis imej untuk pengiraan FFB pada pokok. Dengan menggunakan kumpulan warna  $L^*a^*b^*$ , imej boleh menjadi ditapis untuk mengenal pasti tandan hitam mahupun tandan merah dan hitam padan pokok. Dalam kajian ini, pengesanan imej telah dilakukan dengan menggunakan nilai purata untuk mengenalpasti tandan hitam. Pengesanan penapisan model untuk 48 sampel imej menghasilkan Regression ( $R^2$ ) bernilai 0.8029 untuk mengenal pasti tandan hitam pada setiap pokok. Melalui hasil penyelidikan ini dapat membantu untuk mengotomatisasi sepenuhnya proses untuk mengenal pasti kumpulan tandan pada masa akan datang.

## ACKNOWLEDGEMENTS

During the period of conducting and completing this research, I find it challenging and fun at the same time. Despite challenges faced, I managed to accomplish this research with the help from few parties that lessen the difficulties in carrying out this research. Not to forget, the most important person which contribute towards the accomplishment of this research from the beginning by giving constant advice throughout the process, Dr Muhamad Saufi Bin Mohd Kassim. His toughness and spirits have motivated me day by day and I am extremely thankful and grateful for that.

In addition, I would like to dedicate my appreciation towards lecturers who also taught and share their opinions pertaining to my research study especially in reminding me on the importance of working hard even from the beginning in making sure that this research is done accordingly. I managed to gain new knowledge and valuable lesson throughout the process of completing this research study. I should be more prepared and responsible in making necessary adjustments whenever things do not go as planned. Most importantly, I am very much thankful and grateful to Allah s.w.t for His blessings, helps and a good health condition because without Him, I might not be able to complete this research study.



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:

**Muhamad Saufi Mohd Kassim, PhD**

Senior Lecturer  
Faculty of Engineering  
Universiti Putra Malaysia  
(Chairman)

**Siti Khairunniza bt. Bejo, PhD**

Associate Professor  
Faculty of Engineering  
Universiti Putra Malaysia  
(Member)

---

**ZALILAH MOHD SHARIFF, PhD**

Professor and Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date: 10 June 2021

## TABLE OF CONTENTS

|  | Page      |
|--|-----------|
| <b>ABSTRACT</b>                                    | i         |
| <b>ABSTRAK</b>                                     | iii       |
| <b>ACKNOWLEDGEMENTS</b>                            | v         |
| <b>APPROVAL</b>                                    | vi        |
| <b>DECLARATION</b>                                 | vii       |
| <b>LIST OF TABLES</b>                              | xii       |
| <b>LIST OF FIGURES</b>                             | xiii      |
| <b>LIST OF APPENDICES</b>                          | xvi       |
| <b>LIST OF ABBREVIATIONS</b>                       | xvii      |
| <b>CHAPTER</b>                                     |           |
| <b>1 INTRODUCTION</b>                              | <b>1</b>  |
| 1.1 Overview                                       | 1         |
| 1.2 Problem Statement                              | 2         |
| 1.3 Objectives                                     | 2         |
| 1.4 Research Scope and Limitations                 | 3         |
| <b>2 LITERATURE REVIEW</b>                         | <b>4</b>  |
| 2.1 Oil Palm Malaysia                              | 5         |
| 2.2 Vision Sensor Technology in Agriculture        | 5         |
| 2.3 Data Acquisition Method                        | 6         |
| 2.4 Data Management                                | 7         |
| 2.5 General Counting Implementation in Agriculture | 8         |
| 2.6 Method of Image Analysis                       | 9         |
| 2.7 Software for Image Analysis                    | 10        |
| 2.8 Application Development                        | 12        |
| 2.9 Geospatial Data Tagging                        | 13        |
| 2.10 Oil Palm Tree Fruit Performance               | 14        |
| 2.11 Summary                                       | 14        |
| <b>3 METHODOLOGY</b>                               | <b>15</b> |
| 3.1 Research Material (Flowchart) and Equipment    | 15        |
| 3.2 Development of Research                        | 16        |
| 3.2.1 Data Acquisition                             | 17        |
| 3.2.2 Data Handling                                | 17        |
| 3.2.3 Image Processing                             | 18        |
| 3.3 Equipment and Apparatus                        | 18        |
| 3.3.1 Mobile Platform for Video Acquisition        | 18        |
| 3.3.2 360 Camera                                   | 19        |
| 3.3.3 Gimbal and Monopod                           | 20        |
| 3.3.4 Mounting                                     | 21        |
| 3.3.5 Spotlight                                    | 23        |

|          |   |            |
|----------|---|------------|
| 3.3.6    | Oil Palm Tree Sensing System  | 24         |
| 3.3.7    | Microcontroller   | 26         |
| 3.3.8    | Range Sensor Data Acquisition                                       | 26         |
| 3.4      | Data Collection   | 27         |
| 3.5      | Method of Image Extraction  | 30         |
| 3.6      | Bunch Identification  | 32         |
| 3.6.1    | Pre-Video Processing  | 34         |
| 3.6.2    | Image Processing Technique Using Color Threshold                    | 35         |
| 3.6.3    | Elimination of Unwanted Background Components Using Color Threshold | 35         |
| <b>4</b> | <b>RESULTS AND DISCUSSIONS</b>                                      | <b>49</b>  |
| 4.1      | Moving Pattern of Mobile Platform for Video Acquisition             | 49         |
| 4.2      | Image Handling  | 51         |
| 4.2.1    | Analysis of Range Sensor Data and Image Extraction                  | 51         |
| 4.2.2    | Arrangement of Extracted Images Based on Tree Numbering             | 53         |
| 4.3      | Identification of Bunches Using L*a*b* Color Space                  | 56         |
| 4.3.1    | Analysis of L*a*b* Value for Bunch Identification                   | 56         |
| 4.3.2    | L*a*b* Analysis Based on FFB Color                                  | 60         |
| 4.4      | Image Verification Model Analysis                                   | 61         |
| <b>5</b> | <b>CONCLUSION</b>   | <b>77</b>  |
| 5.1      | Contribution  | 78         |
| 5.2      | Recommendation and Future Work                                      | 78         |
|          | <b>REFERENCES</b>   | <b>80</b>  |
|          | <b>APPENDICES</b>   | <b>84</b>  |
|          | <b>BIODATA OF STUDENT</b>   | <b>103</b> |
|          | <b>LIST OF PUBLICATIONS</b>   | <b>104</b> |

## LIST OF TABLES

| Table |   | Page |
|-------|---|------|
| 4.1   | Advantage and disadvantage for each moving pattern for ATV data acquisition | 50   |
| 4.2   | Distance between tree and ATV based on the data collected from range sensor | 52   |
| 4.3   | Statistical values of L*a*b* color space                                    | 58   |

## LIST OF FIGURES

| Figure |   | Page |
|--------|---|------|
| 2.1    | (a) Three-dimensional representation of L*a*b* color space; (b) Color groups in a* and b* axis based on different value of L                  | 11   |
| 2.2    | Group of colors based on different value of L*  | 12   |
| 3.1    | Research Flowchart  | 15   |
| 3.2    | Aerial view of data collection  | 17   |
| 3.3    | ATV used to be executed in the oil palm plantation  | 19   |
| 3.4    | Samsung 360 Gear Camera   | 19   |
| 3.5    | Panoramic or 360° view angle  | 20   |
| 3.6    | Image of gimbal installed with Samsung 360 Camera   | 21   |
| 3.7    | Disassemble Mounting from ATV   | 22   |
| 3.8    | Mounting mounted on ATV   | 23   |
| 3.9    | Spotlight attached with the mounting on the ATV   | 24   |
| 3.10   | Ultrasonic HC-SR04 Range Sensor   | 25   |
| 3.11   | Wave reflected with an object to identify distance  | 25   |
| 3.12   | Arduino Mega 2560 with the SD Card Reader   | 27   |
| 3.13   | Location of image captured from the camera while the ATV is moving  | 28   |
| 3.14   | A) Image captured when camera is directly perpendicular to the tree; B) Image captured to observe the location of FFB on the side of the tree | 29   |
| 3.15   | A) Method 1; B) Method 2; C) Method 3   | 30   |
| 3.16   | Image extracted stored in files according to file tree  | 32   |
| 3.17   | Process to select Lab threshold value for bunch identification  | 33   |
| 3.18   | Segmentation of tree for image extraction   | 34   |

|      |  |    |
|------|--|----|
| 3.19 | A) unwanted background; B) targeted ROI; C) L*a*b* color histogram   | 36 |
| 3.20 | A) Actual image acquired from oil palm plantation; B) L*, a* and b* intensity value histogram for the image  | 37 |
| 3.21 | A) Initial range value before image threshold for each channel L*, a* and b* color intensity as generated in the code; B) Histogram for L*, a* and b* color intensity which can be modified according to user's intent | 38 |
| 3.22 | A) Removal of sky component in image; B) Modified L* histogram color intensity; C) Channel for L* color intensity range modified in the code   | 39 |
| 3.23 | A) Additional removal of L* color value for further background removal; B) Modified L* histogram color intensity; C) Channel for L* color intensity range modified in the code   | 40 |
| 3.24 | A) Removal of green components such as leaves and grass in image; B) Modified a* histogram color intensity; C) Channel for a* color intensity range modified in the code   | 41 |
| 3.25 | A) Removal of yellowish-brown color component such as trunk and fronds in image; B) Modified b* histogram color intensity; C) Channel for b* color intensity range modified in the code                                | 42 |
| 3.26 | A) Further adjustment of L* to enhance the FFB figure; B) Modified L* histogram color intensity; C) Channel for L* color intensity range modified in the code  | 43 |
| 3.27 | A) RGB image converted into binary image; B) Modified L* histogram color intensity; C) Channel for L* color intensity range modified in the code   | 44 |
| 3.28 | A) Background color was changed into white; B) Figure of FFB; C) Zoomed in figure of FFB   | 45 |
| 3.29 | A) Zoomed in of unwanted background after threshold; B) Zoomed in of targeted ROI after threshold  | 46 |
| 3.30 | A) Threshold image ready for bunch identification; B) Export tools to generate function from threshold image   | 47 |
| 3.31 | Generated syntax for each channel color intensity value range  | 48 |
| 4.1  | Image extraction for both side of tree   | 53 |
| 4.2  | Image numbering covered the whole part of a tree   | 54 |

|      |   |    |
|------|---|----|
| 4.3  | Position of lens for image extraction   | 55 |
| 4.4  | Results of image threshold using L*a*b* color space   | 57 |
| 4.5  | L*a*b* color intensity value against image number   | 59 |
| 4.6  | L* color intensity value against image number for black bunch   | 62 |
| 4.7  | a* color intensity value against image number for black bunch   | 63 |
| 4.8  | b* color intensity value against image number for black bunch   | 64 |
| 4.9  | Syntax for image verification based on mean value of L*a*b* color space   | 66 |
| 4.10 | A) Original RGB output; B) Model threshold image  | 67 |
| 4.11 | A) 1 <sup>st</sup> segment; B) 2 <sup>nd</sup> segment; C) 3 <sup>rd</sup> segment  | 67 |
| 4.12 | Position of ROI according to image extraction sequence for both side of each tree   | 69 |
| 4.13 | A) Visible unwanted background elements captured in original RGB image; B) Visible unwanted background elements captured in model threshold image | 70 |
| 4.14 | A) Actual number of FFB on the original RGB image; B) 3 visible round edges of FFB on the tree crown from model threshold image                   | 71 |
| 4.15 | A) Frond B) Figure of FFB   | 71 |
| 4.16 | A) 1 <sup>st</sup> image; B) 2 <sup>nd</sup> Image; C) 3 <sup>rd</sup> Image  | 72 |
| 4.17 | A) Original RGB Image; B) Clear visible FFB in model threshold image output   | 74 |
| 4.18 | Data distribution of FFB counting between original RGB and model threshold image  | 75 |

## LIST OF APPENDICES

| Appendix |  | Page |
|----------|--|------|
| A        | Allocation of images extracted into specific tree folder   | 84   |
| B        | Mathematical formula to extract images for each tree   | 85   |
| C        | Extraction of images for both side of a tree based on data from range sensor   | 86   |
| D        | L*a*b* Color Intensity Value   | 88   |
| E (a)    | L* color intensity value against image number  | 90   |
| E (b)    | a* color intensity value against image number  | 90   |
| E (c)    | b* color intensity value against image number  | 91   |
| F        | Mean Intensity Value of L*a*b* color space for black FFB   | 92   |
| G        | Mean Intensity Value of L*a*b* color space for black and red FFB   | 94   |
| H        | Image Verification using Model Generated from Image Analysis   | 95   |
| I        | Image Verification FFB Counts Between Original RGB and Model Threshold Image Using Model Generated from Image Analysis | 100  |
| J        | Data presented based on the reading of range sensor in Arduino IDE   | 102  |



## LIST OF ABBREVIATIONS

|                |  |
|----------------|--|
| UPM            | Universiti Putra Malaysia              |
| ATV            | All-Terrain Vehicle                    |
| FFB            | Fresh Fruit Bunch                      |
| R <sup>2</sup> | Coefficient of Determination           |
| FELDA          | Federal Land and Development Authority |
| DOF            | Degrees of Freedom                     |
| 3D             | Three-dimensional                      |
| CMOS           | Metal Oxide Semiconductor              |
| CCD            | Charge-coupled Device                  |
| ARD            | Agricultural and Rural Development     |
| 2D             | Two-dimensional                        |
| POV            | Point of View                          |
| IDE            | Integrated Development Environment     |
| ROI            | Region of Interest                     |
| GUI            | Graphical User Interface               |

# CHAPTER 1

## INTRODUCTION

### 1.1 Overview

Agricultural expansion is one of the leading causes of deforestation in the tropics and in Southeast Asia was driven by large-scale production for international trade. Peninsular Malaysia has wide history of plantation agriculture which has been a predominantly resource-based economy where expanding plantations such as oil palm continue to replace natural forests (Shevade et al., 2019). According to Corley et al. (2009), by 2050 oil palm demand will probably reach 240Mt. In order to fulfill such demand an improved field management system need to be considered especially in harvesting operation. In every cycle of harvesting operation, farmer does not have any information on how many bunches and which oil palm tree will be harvested. By implementing 360° view imaging technology, farmer or plantation manager can use this information to manage their workers, machines and other agricultural recourses. Rapid and efficient decision-making process is one of the important aspects that need to be considered for effective and well-organized data collection for big scale plantation area. In order to achieve this target, the exact number of bunches of each tree need to be identified. FFB weight and total number of bunches are two major parameters used to estimate the salary of harvester in oil palm estates. Worker's salary per harvested bunch and total count of bunches can be easily projected in advance and yield for every harvesting cycle could easily be calculated. New trend of agricultural practices and agricultural consumer demand requires early information on yield and quality of the agricultural product. Availability of this information enables effective field management.

Kassim et al. (2009) developed a color imaging models to determine maturity stages of FFB. By color imaging technique, the date of harvesting could be estimated. With a systematic data of harvesting schedule, FFB yield also can be forecasted as well as the performance of oil palm tree, which also enable additional feature in producing the harvesting map to support the operation of site-specific harvesting. Black bunch census technique could not be implemented in plantation scale since the operation of image data collection was time consuming and tedious process due to the height of the oil palm tree and position of the oil palm bunches. In this research, rapid imaging system will be explored in order to overcome the problems and to develop 360° imaging system. Thus, this system also aims to collect comprehensive data of oil palm tree focusing in the application of big scale oil palm plantation area. This project focusing on the developing 360° vision system to identify the figure of FFB on each palm oil tree. Plantation management can estimate the yield production of the FFB. A 360° camera view of oil palm tree will be captured to obtain a best image for better analysis and interpretation of the FFB for each tree.

## 1.2 Problem Statement

Current technologies to determine the number of FFB on tree crown requires a long period of time where farmers need to approach each tree in order to have a clear view of FFB located at each tree crown. Some of the tree in the oil palm plantation area grows in different height, which depends on the age of the tree itself thus it does affect in the aspect of ergonomically for the data collection. Jayaselan et al. (2012) stated that machine automation technology is an alternative to optimize the number of workers as well as to provide comfortable ergonomic working condition. Nawi et al. (2013) conducted a study for the evaluation of working posture during harvesting oil palm fresh fruit bunches. In addition, he stated that ergonomics plays an important role to improve occupational health and work productivity in most industries in Malaysia including agriculture. However, most of the workers in Malaysia especially in oil palm plantation failed to emphasize regarding ergonomics awareness as priority for their safety and health by still using manual tools and consequently exposed to ergonomics risk factors. This operation is tedious and requires plantation manager to hire workers to count FFB manually on the tree crown especially in large plantation scale. Systematic information about number of bunches on each tree will be useful to perform precise oil palm harvesting operation. In addition, due to the high oil palm tree in the palm oil plantation, it is hard for farmers to have a clear view of the FFB to identify the number of FFB on each tree. Thus, the data may not be accurate due to unclear view of the FFB on the tree. With the 360° view of the FFB, it is possible for farmers to get a clear and closer view of the bunch. By introducing the 360° view imaging technique, a large plantation area will not be a problem for the process of data collection. Other problem found is the sorting and storing data for each oil palm tree where nowadays, data are collected manually in field. With the 360° view imaging technique, a large data collection can be stored in a controlled manner. Data sorting of attributes for each oil palm tree can be easily retrieve from the database in the software.

## 1.3 Objectives

The main objective of this project is to develop a 360° view imaging model for the identification of FFB in oil palm plantation area. In order to develop a 360° view imaging model for FFB identification, the following objectives were carried out in this research:

1. To develop 360° view imaging system using 360° camera for data acquisition in oil palm plantation area.
2. To develop image processing model using  $L^*a^*b^*$  color space for bunch identification.
3. To verify model using mean value of  $L^*a^*b^*$  color space generated from analysis of images.

#### 1.4 Research Scope and Limitations

1. This study focuses on the development of 360° view imaging model for the identification of oil Palm (*Elaeis Guineensis*) FFB in oil palm plantation area located in Universiti Putra Malaysia (UPM).
2. This study includes the determination of moving pattern on Polaris Sportsman 550HP ATV as a mover to acquire data in form of video to acquire FFB data in plantation environment. Image and range data extraction was done using MATLAB 9.4 version R2018a (2018) software. The range data was acquired by using HC-SR04 Ultrasonic (US) range sensor during the video recording in the oil palm plantation area.
3. L\*a\*b\* color space was selected as features to develop the model. The selected mean threshold value of L\*a\*b\* was used in the process of FFB identification and unwanted background removal.
4. This project is up to the identification of FFB on tree crown based on the final mean threshold value of L\*a\*b\* (result from item 3) and verification of the developed model in oil palm plantation environment.

## REFERENCES

- Alberto-Rodriguez, A., Neri-Muñoz, M., Ramos-Fernández, J. C., Márquez-Vera, M. A., Ramos-Velasco, L. E., Díaz-Parra, O., & Hernández-Huerta, E. (2020). Review of control on agricultural robot tractors. *International Journal of Combinatorial Optimization Problems & Informatics*, 11(3), 9–20.
- Antonopoulou, E., Karetzos, S. T., Maliappis, M., & Sideridis, A. B. (2010). Web and mobile technologies in a prototype DSS for major field crops. *Computers and Electronics in Agriculture*, 70(2), 292-301.
- Chang, Y. K., Zaman, Q. U., Farooque, A., Chattha, H., Read, S., & Schumann, A. (2017). Sensing and control system for spot-application of granular fertilizer in wild blueberry field. *Precision Agriculture*, 18(2), 210-223.
- Chiang, C. Y., Chen, K. S., Chu, C. Y., Chang, Y. L., & Fan, K. C. (2018). Color enhancement for four-component decomposed polarimetric SAR image based on a CIE-Lab encoding. *Remote Sensing*, 10(4), 545. <https://doi.org/10.3390/rs10040545>
- Corley, R. H. V. (2009). How much palm oil do we need?. *Environmental Science & Policy*, 12(2), 134-139.
- Grossetete, M., Berthoumieu, Y., Da Costa, J. P., Germain, C., Laviaille, O., & Grenier, G. (2012, July). Early estimation of vineyard yield: site specific counting of berries by using a smartphone. *In International Conference of Agricultural Engineering—CIGR-AgEng*.
- Holly, R., (12 April, 2017). Samsung Gear 360 (2017) vs. Gear 360 (2016): What's different, what's better. Retrieved from *androidcentral*: <https://www.androidcentral.com/samsung-gear-360-2017-vs-gear-360-2016>
- Hudzari, R. M., Ssomad, M. A. H. A., Syazili, R., & Fauzan, M. Z. M. (2012). Simulation and modeling application in agricultural mechanization. *Modelling and Simulation in Engineering*, 2012. <https://doi.org/10.1155/2012/381239>
- Ilyana, A., Hasrulnizzam, W., Mahmood, W., Fazli, M. H., Fauadi, M., Nizam, M., ... & Fathiyah, A. J. (2015). Sustainability in Malaysian palm oil: a review on manufacturing perspective. *Polish Journal of Environmental Studies*, 24(4), 1463-1475. <https://doi.org/10.15244/pjoes/37888>
- Jaffar, A., Jaafar, R., Jamil, N., Low, C. Y., & Abdullah, B. (2009). Photogrammetric grading of oil palm fresh fruit bunches. *Int. J. Mech. Mechatron. Eng*, 9(10), 7-13.

- Jayaselan, H. A. J., Ismail, W. I. W., & Ahmad, D. (2012). Manipulator automation for Fresh Fruit Bunch (FFB) harvester. *International Journal of Agricultural and Biological Engineering*, 5(1), 7-12. [https://doi: 10,3965/j.ijabe.20120501.002](https://doi.org/10.3965/j.ijabe.20120501.002)
- Kassim, M. S. M., Ismail, W. I. W., Ramli, A. R., & Bejo, S. K. (2012). Oil palm fresh fruit bunches (FFB) growth determination system to support harvesting operation. *Journal of Food, Agriculture & Environment*, 10(2), 620-625.
- Kise, M., Zhang, Q., 2008. Creating a Panoramic Field Image Using Multi-Spectral Stereovision System. *Computers and Electronics in Agriculture* 60(1), 67-75.
- Lal, S., Behera, S. K., Sethy, P. K., & Rath, A. K. (2017, May). Identification and counting of mature apple fruit based on BP feed forward neural network. In *2017 Third International Conference on Sensing, Signal Processing and Security (ICSSS)* (pp. 361-368). [https://doi: 10.1109/SSPS.2017.8071621](https://doi.org/10.1109/SSPS.2017.8071621).
- Lin, T. T., Hsiung, Y. K., Hong, G. L., Chang, H. K., & Lu, F. M. (2008). Development of a virtual reality GIS using stereo vision. *Computers and electronics in agriculture*, 63(1), 38-48.
- Liu, Z., Zheng, W., Wang, N., Lyu, Z., & Zhang, W. (2020). Trajectory tracking control of agricultural vehicles based on disturbance test. *International Journal of Agricultural and Biological Engineering*, 13(2), 138-145.
- Lottes, P., Hörferlin, M., Sander, S., & Stachniss, C. (2017). Effective vision-based classification for separating sugar beets and weeds for precision farming. *Journal of Field Robotics*, 34(6), 1160-1178. doi: 10.1002/rob.21675
- Lowenberg-DeBoer, J., Huang, I. Y., Grigoriadis, V., & Blackmore, S. (2020). Economics of robots and automation in field crop production. *Precision Agriculture*, 21(2), 278–299. <https://doi.org/10.1007/s11119-019-09667-5>
- Nawi, N. S. M., Deros, B. M., & Nordin, N. (2013). Assessment of Oil Palm Fresh Fruit Bunches Harvesters Working Postures Using Reba. *Advanced Engineering Forum*, 10, 122–127. <https://doi.org/10.4028/www.scientific.net/AEF.10.122>
- Qiang, C. Z., Kuek, S. C., Dymond, A., & Esselaar, S. (2012). Mobile applications for agriculture and rural development.
- Qureshi, W., Payne, A., Walsh, K., Linker, R., Cohen, O., & Dailey, M. (2017). Machine vision for counting fruit on mango tree canopies. *Precision Agriculture*, 18(2), 224–244. <https://doi.org/10.1007/s11119-016-9458-5>

- Rafoss, T., Sælid, K., Sletten, A., Gyland, L. F., & Engravslia, L. (2010). Open geospatial technology standards and their potential in plant pest risk management—GPS-enabled mobile phones utilizing open geospatial technology standards Web Feature Service Transactions support the fighting of fire blight in Norway. *Computers and Electronics in Agriculture*, 74(2), 336-340.
- Rasti, P., Ahmad, A., Samiei, S., Belin, E., & Rousseau, D. (2019). Supervised image classification by scattering transform with application to weed detection in culture crops of high density. *Remote Sensing*, 11(3), 249. [https://doi: 10.3390/rs11030249](https://doi.org/10.3390/rs11030249)
- Razali, M. H., Ismail, W. I. W., Ramli, A. R., Sulaiman, M. N., & Harun, M. H. (2009). Development of image based modeling for determination of oil content and days estimation for harvesting of fresh fruit bunches. *International Journal of Food Engineering*, 5(2).
- Sallabi, F., Fadel, M., Hussein, A., Jaffar, A., & El Khatib, H. (2011). Design and implementation of an electronic mobile poultry production documentation system. *Computers and electronics in agriculture*, 76(1), 28-37.
- Sethy, P. K., Panda, S., Behera, S. K., & Rath, A. K. (2017). On tree detection, counting & post-harvest grading of fruits based on image processing and machine learning approach-a review. *International Journal of Engineering & Technology*, 9(2), 649-663.
- Shamshiri, R. R., Hameed, I. A., Pitonakova, L., Weltzien, C., Balasundram, S. K., Yule, I. J., Grift, T. E., & Chowdhary, G. (2018). Simulation software and virtual environments for acceleration of agricultural robotics: Features highlights and performance comparison. *International Journal of Agricultural & Biological Engineering*, 11(4), 15–31. <https://doi.org/10.25165/j.ijabe.20181104.4032>
- Shamshiri, R. R., Weltzien, C., Hameed, I. A., Yule, I. J., Grift, T. E., Balasundram, S. K., Pitonakova, L., Ahmad, D., & Chowdhary, G. (2018). Research and development in agricultural robotics: A perspective of digital farming. *International Journal of Agricultural & Biological Engineering*, 11(4), 1–14. <https://doi.org/10.25165/j.ijabe.20181104.4278>
- Shevade, V. S., & Loboda, T. V. (2019). Oil palm plantations in Peninsular Malaysia: Determinants and constraints on expansion. *PLoS ONE*, 14(2), 1–22. <https://doi.org/10.1371/journal.pone.0210628>
- Shiddiq, M., Salambue, R., Poja, R., & Solistio, A. T. (2017). Analysis of Physical Properties of Oil Palm Fresh Fruit Bunches Using ImageJ,”. *Applied Science Technology*, 1.

- Sinecen, M., Temizkan, R., & Caner, C. (2015). Investigation of the Morphological and Color Changes of Damaged Green Plums During Storage Time Using Digital Image Processing Techniques. *Gazi University Journal of Science*, 28(1), 133-139.
- Slaughter, D. C., Giles, D. K., & Downey, D. (2008). Autonomous robotic weed control systems: A review. *Computers and electronics in agriculture*, 61(1), 63-78.
- Srestasathiern, P., & Rakwatin, P. (2014). Oil palm tree detection with high resolution multi-spectral satellite imagery. *Remote Sensing*, 6(10), 9749-9774. [https://doi: 10.3390/rs6109749](https://doi.org/10.3390/rs6109749)
- Syal, A., Garg, D., & Sharma, S. (2013). A survey of computer vision methods for counting fruits and yield prediction. *International Journal of Computer Science Engineering*, 2(6), 346-350.
- Tanigaki, K., Fujiura, T., Akase, A., Imagawa, J., 2008. Cherry-Harvesting Robot. *Computers and Electronics in Agriculture*, 63(1), 65-72.
- Vakilian, K. A., & Massah, J. (2012). Performance evaluation of CCD and CMOS cameras in image textural features extraction. *Acta Technica Corviniensis-Bulletin of Engineering*, 5(3), 61.
- Wan Ishak, W.I., & Razali, M. H. (2010). Image based modeling for oil palm fruit maturity prediction. *International Journal of Food, Agriculture and Environment*, 8(2), 469-476.
- Yoshizaki, T., Shirai, Y., Hassan, M. A., Baharuddin, A. S., Abdullah, N. M. R., Sulaiman, A., & Busu, Z. (2013). Improved economic viability of integrated biogas energy and compost production for sustainable palm oil mill management. *Journal of Cleaner Production*, 44, 1-7.



## BIODATA OF STUDENT

The student, Izat Jaris bin Dzulkifli as born on 1<sup>st</sup> of February 1993 in Ipoh, Perak. He received his primary education at Sekolah Kebangsaan Puchong Utama 2, Puchong. He continued his secondary education at Sekolah Menengah Kebangsaan Puchong Utama 1, Puchong (Form 1-2) and Sekolah Menengah Sains Bagan Datoh, Perak (Form 4-5). He pursues his study for foundation program in Universiti Putra Malaysia in Foundation Studies for Agricultural Science. After a year, he proceeds his degree program for four years at Universiti Putra Malaysia and graduated with a Bachelor of Engineering (Agricultural and Biosystem) in 2016. He is now currently a postgraduate student for the Master of Science degree in Mechanization and Automation in Agriculture from Universiti Putra Malaysia. As for now he is currently an employee of Accenture Technology Solution Sdn Bhd.

## LIST OF PUBLICATIONS

### Journals

**Dzulkifli, Izat Jaris.,** Muhamad Saufi Mohd Kassim, Siti Khairunniza Bejo. (2020). Development of 360-degree imaging system for fresh fruit bunch (FFB) identification. *Journal of Agricultural and Food Engineering*, 4 (2020): 0028. <http://doi.org/10.37865/jafe.2021.0028>

### Proceeding

**Dzulkifli, Izat Jaris.,** Muhamad Saufi Mohd Kassim., (2018). Development of 360-degree imaging model for fresh fruit bunch – preliminary study: bunch identification. MSAE Conference, Serdang, Selangor D.E, Malaysia. 7 & 8 February 2018