Journal of Agricultural and Food Engineering 4 (2020) 0028
Journal homepage: www.myjafe.com
DOI: http://doi.org/10.37865/jafe.2021.0028
e-ISSN: 2716-6236

Research Article

Development of 360-degree imaging system for fresh fruit bunch (FFB) identification

Izat Jaris Dzulkifli*, Muhamad Saufi Mohd Kassim , Siti Khairunniza Bejo

Department of Biological and Agricultural Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia.

ARTICLE HISTORY

Received: 26 October 2020
Received in revised form: 20 December 2020
Accepted: 7 February 2021
Available Online: 27 February 2021

Keywords
Black bunch census
360° view camera
Video acquisition
Video image processing

Abstract

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 the 360° camera imaging system, number of Fresh Fruit Bunch (FFB) can be determined for every tree in a plantation area. Black bunch census was done manually to estimate yield. This was improved by video acquisition using a high resolution 360° camera integrated with an image processing software for video image processing to calculate number of FFB. Based on the standard planting pattern, it is time consuming process to circle each tree to acquire the 360° view of each tree. Current technology to approach bunches is destructive and conventional since the process involve physical contact between workers and FFB. Thus, a new method was established by the execution of All-Terrain Vehicle (ATV) between rows in plantation area for video acquisition. Images were extracted and threshold by using MATLAB software. L*, a*, and b* color space was used for the bunch identification throughout 90 samples of images to identify the mean intensity value. Model threshold verification for another 48 samples of images resulted with Coefficient of Determination, R^2 of 0.8029 for bunch identification. As a result, a new method for video acquisition was established as well as processing method for bunch identification for large scale plantation area.

1.0 Introduction

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 fulfil such demand, an improved field management system need to be considered especially in harvesting operation. A study review was done by Ilyana et al. (2015) regarding the manufacturing perspective on the current sustainability effort and identifies the drivers for sustainability, especially in Malaysia since it controls the majority of almost 50 percent of the worldwide market share of export.

Number of FFB on each tree is an important parameter for planning and yield prediction for oil palm plantation area. Black bunch census which refers to manual bunch counting for the determination of FFB counts 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. In terms of ergonomically, different height of each tree in oil palm plantation area brings impact for data collection of FFB. This is due to the height of each tree which depends on the age of the tree. Thus, the data may not be accurate due to unclear view of the FFB on the tree. Slaughter et al. (2008) also stated that one of the alternatives to provide a means of reducing agriculture's current dependency on herbicides, improving its sustainability, and reducing its environmental impact is by implementing the robotic technology. Thus, oil palm industries are eager to look forward to better production of oil palm with new and better techniques in mechanization since the cost for labor is increasing. By implementing more efficient mechanization skills, the labor cost can be cut and saved without reducing the production of oil palm to maximize the profit. Other problem found is the storing and sorting data for each oil palm tree where nowadays, data are collected manually in field.

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 large scale plantation area. In order to achieve this target, the exact number of bunches of each tree need to be determined accurately. 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, total count of bunches and yield for every harvesting can be easily projected in advance.

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. This research is focusing on how the data collection process is done especially in large plantation scale area since nowadays rapid and accurate data collection in plantation area is needed corresponding with many modern and high-tech devices established in the market. With the 360° view of the FFB, it is possible for farmers to get a clear and closer view of the bunches especially in large scale plantation area. Apparatus and instruments used in data collection process include ATV, 360 Camera, ultrasonic sensor, spotlight, and computers.

Generally, counting is one of the methods to acquire the number of fruits existing on each tree for a certain agriculture area. A bigger scale of agriculture area contributes a bigger number of trees thus the number of fruits is larger. Thus, it is important to justify the best method for counting technique in order to save time and more systematic data storage. Lal et al. (2017) stated that classification of fruits is time consuming and tedious action since the number of fruits in a certain tree can become countless since the general counting technique of fruits is based on the naked eye observation and detection. Thus, an advanced technique in image processing and machine learning

*Corresponding author email: izatjaris93@gmail.com

helps to automatically classify and count the fruits with better accuracy without bringing any destruction to the fruits. Razali et al. (2009) stated that current technology in determining the maturity of FFB is destructive and conventional. In this research, a vision-based system for data collection was used to acquire visual data for FFB analysis since this technique does not bring any destruction or damage to FFB. The benefits of utilizing these techniques are because of its simplicity, non-destructive and modest techniques that do not require any complex apparatus for the process (Sinecen et al., 2014). Sethy et al. (2017) conducted a study regarding image processing and machine vision technique to detect and count of fruits on-tree directly in field condition. Numerous types of algorithms are available for counting and extracting the features of fruit characters using RGB camera to capture on-tree fruit images. Qureshi et al. (2016) in one of his study developed a vision-based machine of automated counting of fruits on mango tree canopies for rapid and accurate yield production in the field. Two strategies that were proposed in the research was utilizing texture-based dense segmentation and the other one using shape-based fruit detection hence comparing the effectiveness of these two methods in relative with existing techniques in the field.

New trend of agricultural practices and agricultural consumer demand require early information on yield and quality of the agricultural product. Availability of this information enables effective field management. Grossetete et al. (2012), stated that in order to improve site specific management, early yield estimation technique must be accurate and efficient so the profitability can be increased. Introduction of 360° view imaging can improve in terms of data collection and data handling for large scale plantation area. Created database provide advantages in data retrieval, data analysis and prediction which are important aspects in modern agriculture especially in Agricultural 4.0, smart farming, and precision farming. Farmer or plantation manager may use this information to manage their workers, machines, and other agricultural recourses. Syal et al. (2013) stated that the problem of determining the number of fruits on trees has long been on interest in the agricultural crop field where until now many studies were conducted in the development of crops recognition using computer vision and image processing techniques.

In this research, several tests have been done in order to determine the best distance between camera and tree to achieve the best video quality. Video quality refers to the visibility of oil palm bunches on each tree in every angle so that all the oil palm bunches can be seen clearly for further counting process to be done in the processing software. The main idea is to implement the generated algorithm in the 360° view imaging system to identify the number of bunches directly from the video recorded from the plantation. Since the FFB images were analysed by using programming MATLAB function, a potential model for sorting and grading for FFB could be generated in order to skip the sorting and grading of FFB process manually. This can improve in the aspect of data management of the oil palm plantation mill.

2.0 Materials and methods

This research focuses on the method of collecting data for FFB identification for each tree in large scale oil palm plantation. Generally, data collection process involves video recording in the oil palm plantation area along the rows between the oil palm trees. The recorded data will be processed and analyzed using image processing software. The data was collected at oil palm plantation area in Universiti Putra Malaysia (UPM) located at 2.988041(N), 101.727623(E). The average height of oil palm tree is roughly around 5 meters and the tree crown usually situated 3 meters from the ground. The condition of the ground in the oil palm plantation area is commonly flat with soft soil condition.

Figure 1 shows the research flowchart of the research activities which shows data acquisition from the oil palm plantation area up to the FFB identification. In order to identify FFB for each tree, L*, a*, and b* color space was selected as the main feature. The video then was processed for the extraction of images containing the figure of FFB bunches. These images were further analyzed to determined L*, a*, and b* value for image threshold to remove unwanted background which include sky, fronds, grass and tree trunks. The mean color intensity of L*, a*, and b* value was used to identify the FFB in images. The reliability of the L*, a*, and b* mean values were measured by calculating the percentage of accuracy. The percentage of accuracy was determined using a Regression, R^2 model by comparing the visibility of FFB after threshold and the actual number of FFB present on each tree.

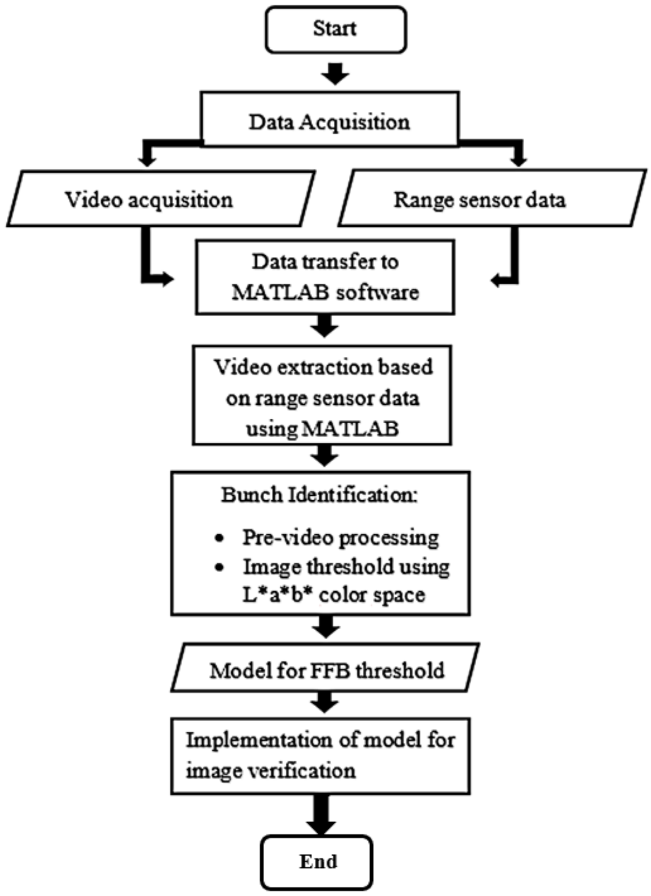

Figure 1. Research flowchart

2.1 Equipment and Apparatus

In order to generate data collection system for the bunch identification, combinations of mobile platform and optical sensor were executed directly in the oil palm plantation area. Optical and other sensors were attached on the same mobile platform in order for the data collection process to be executed on the same time.

2.1.1 Mobile Platform

A mobile platform is required to carry all the equipment for data collection in the oil palm plantation area. All-Terrain Vehicle (ATV) was used as the mobile platform along with the installation of Samsung 360 Camera, adjustable monopod, anti-vibration stabilizer, spotlight, and Ultrasonic sensor. An oil palm tree sensing system was developed throughout the data collection process which include ultrasonic sensor, microcontroller, and software for the video image processing. The cylinder capacity of the ATV is 550HP manufactured by Polaris which is capable for the data collection in the oil palm plantation area. The height of the ATV is around 1.5 meter from the ground which is suitable for the camera and sensor to collect data efficiently.

2.1.2 360 Camera and Gimbal

Samsung 360 Camera was used as a vision sensor to collect two-dimensional (2D) data of oil palm tree in the oil palm plantation as shown in Figure 2(A). Samsung 360 Camera was used to record videos of oil palm tree in the oil palm plantation. The video started to record when the ultrasonic sensor sensed the presence of tree. When the sensor detected 1.5 m gap between the camera and oil palm tree, the ultrasonic sensor will send signal to the controller to record the data. The data was used in the image extraction process where only images containing the tree crowns were extracted from the video file. To achieve the best accuracy, the recorded video must be synchronized with the timestamp of the ultrasonic sensor throughout the data collection process.

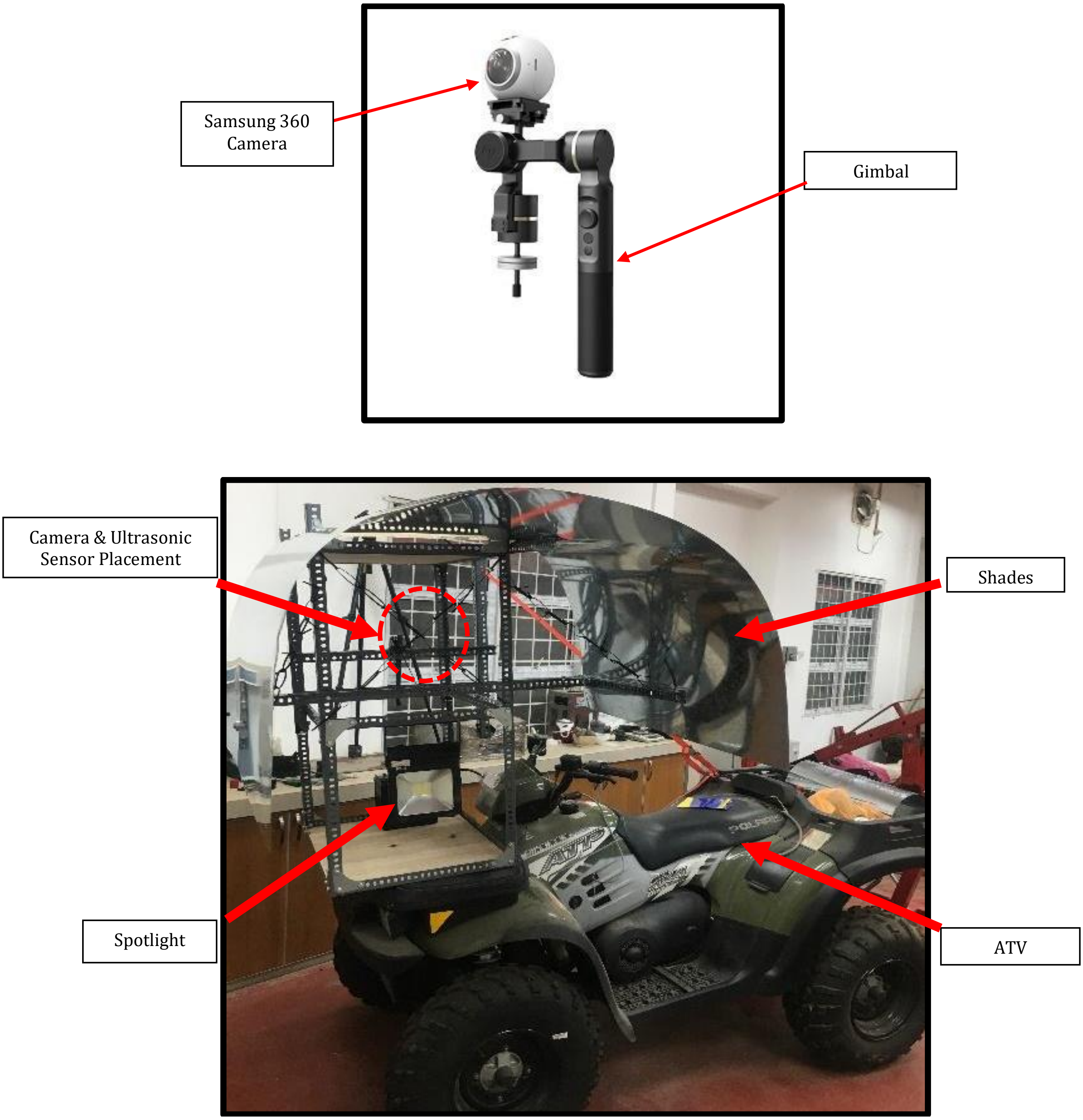

Figure 2. (A) Samsung 360 Gear Camera (B) Mounting mounted on ATV

The camera was equipped with an external slot for micro SD card used to store the video taken in the oil palm plantation area in .MP4 format. The camera has dual lens situated in front and rear of the camera Both lenses have different resolutions and can be used either one or both side of lenses. The resolution of the video using dual lens and single lens are 2560 x 1440 and 3840 x 2160 respectively. Both videos were taken either from single lens or dual lens are 24 fps. Each individual side of the lens can cover up to 180° of view with rectangular 16:9 video and image size. Both lenses could generate panoramic images from both front and rear camera to cover 360° angle for each tree.

The camera was attached with a gimbal and monopod as shown in Figure 2(A) to support and to stabilize the camera throughout the video recording process. This gimbal was installed with 3D motion stabilizer in which can reduce the noise in 3 different axes since the ATV is moving on uneven surface in the plantation area. By doing this, video can be recorded with a better video quality. The camera and gimbal were mounted in front of the ATV parallel with the Ultrasonic sensor and spotlight. The front lens of the camera is facing the tree for the best video recording result of the tree crown of each tree.

2.1.3 Mobile Platform Mounting

A structure of steel was constructed as a platform to install equipment such as camera, monopod, gimbal, microcontroller, spotlight, power supply, and ultrasonic sensor. The mounting structure was also equipped with aluminum plate which acted as a shield in order to prevent the oil palm tree fronds to make any contact with the camera. Aluminum was chosen since aluminum is one of the materials that acted as a reflector of light since the spotlight is located under the shield. Test has been conducted and it shows that the light supply from the spotlight was reflected directly to the target bunch area on the tree which gives a better view of the bunches. The structure was installed at the front side of the ATV since it is easier for driver to operate all the system simultaneously as shown in Figure 2(B). However, the driver still can access the front view of the ATV in order to maneuver the ATV.

2.1.4 Spotlight

Since the oil palm plantation area was covered with the tree canopy, the light intensity of all the video taken is not constant depending on the position of the sun. This cause the bunch could not be identified when the light intensity is too low. Additional lighting was installed to support the natural light intensity throughout the video recording process due to inconsistent light intensity under the canopy of oil palm tree in the plantation area. This waterproof 100W outdoor LED flood light is made of high-quality aluminum and toughened glass, featuring high luminous efficiency and low power consumption. High luminous efficiency, about 80 %-90 % light utilization rate with long lived performance. A DC battery power was converted to AC through the inverter attached on the ATV to power up the spotlight for optimum usage. The color of the light is in cool white color range from 6000 up to 6500 Kelvin. Using additional light intensity supply, the video will have uniform and constant luminance light intensity throughout the video recording process. With constant light intensity, the process of video image processing can be eased for the detection of bunches on each tree regardless the position of bunches on the oil palm tree. The spotlight was set to be angled at 45° from the ground facing upwards or directly to the tree crown while the camera was maintained facing the tree since the camera lens equipped with wide angle.

2.1.5 Oil Palm Tree Sensing System

The sensing system consist of HC-SR04 Ultrasonic sensor installed parallel with the lens of the camera. The camera and ultrasonic sensor were operated simultaneously as the data of both sensors need to be processed for image extraction. The measurement range of the ultrasonic sensor was fixed 1.5 m between the camera and oil palm tree. HC-SR04 Ultrasonic sensor is a 4-pin sensor module, uses the principle of echolocation to measure distance. The measurement range of the ultrasonic sensor could reach up to 4.5 meter.

When the ATV is moving in the pathway while the video is being recorded, the ultrasonic sensor will also detect the obstacles which refers as the tree. Thus, when the ultrasonic sensor detected any tree, the data will be recorded by the controller. The data from the ultrasonic sensor was used to be as a reference for the image extraction process.

2.1.6 Ultrasonic Sensor Data Acquisition

Along with the HC-SR04 Ultrasonic sensor, Arduino Mega 2560 was used as the controller to control the activity of ultrasonic sensor to collect distance data. SD Card Reader was attached to store the data collected from the ultrasonic sensor. The capacity of the SD card is 1GB. The data stored in the SD Card was transferred to the computer for data analysis.

All the data is stored in micro SD card in .txt format. The data is saved in excel file and used to assist in the image extraction process. The timestamp data from the ultrasonic sensor was used as a reference for the extraction of desired images of clearly visible tree crown. By doing this, the process of image extraction can be done without manually scanning the whole video to extract useful images of tree.

2.2 Data Collection

The best ATV moving pattern was determined by considering the best configuration to get the whole 360° view of each tree. The ATV carrying the sensing system moves between the oil palm tree along the route in the plantation area as shown is Figure 3. There are three methods, the first method ATV will move according to the pathway between the trees in each row as shown in Figure 3(A). This method utilizes both lenses of the camera. The second moving pattern requires the ATV to circle each tree to acquire video as shown in Figure 3(B). The third method established as in Figure 3(C) requires the ATV to move twice in each pathway between trees to acquire video which only use one lens of the camera. Thus, only one single path is required to collect the videos of two rows of oil palm trees.

Camera lens is capable to acquire 180° wide angle image by using one side of the camera lens to acquire side view of each tree in the plantation. Images from both side of each tree will be combined in image processing software to produce panoramic view of the whole view of a tree for the bunch identification process.

2.3 Method of Image Extraction

After the video has been acquired from the plantation area, image extraction was done before proceeding with image processing for bunch identification. Image extraction was done using MATLAB 9.4 version R2018a (2018) software where the extraction was done based on the data collected by the range sensor. Output data from ultrasonic sensor includes the timestamps and distance. A function was created to call in the video file into MATLAB for image extraction. The data from the range sensor shows the video timeframe capturing only the image of trees throughout the data collection process as shown in Method 3. In other words, when the ATV is passing by a tree,

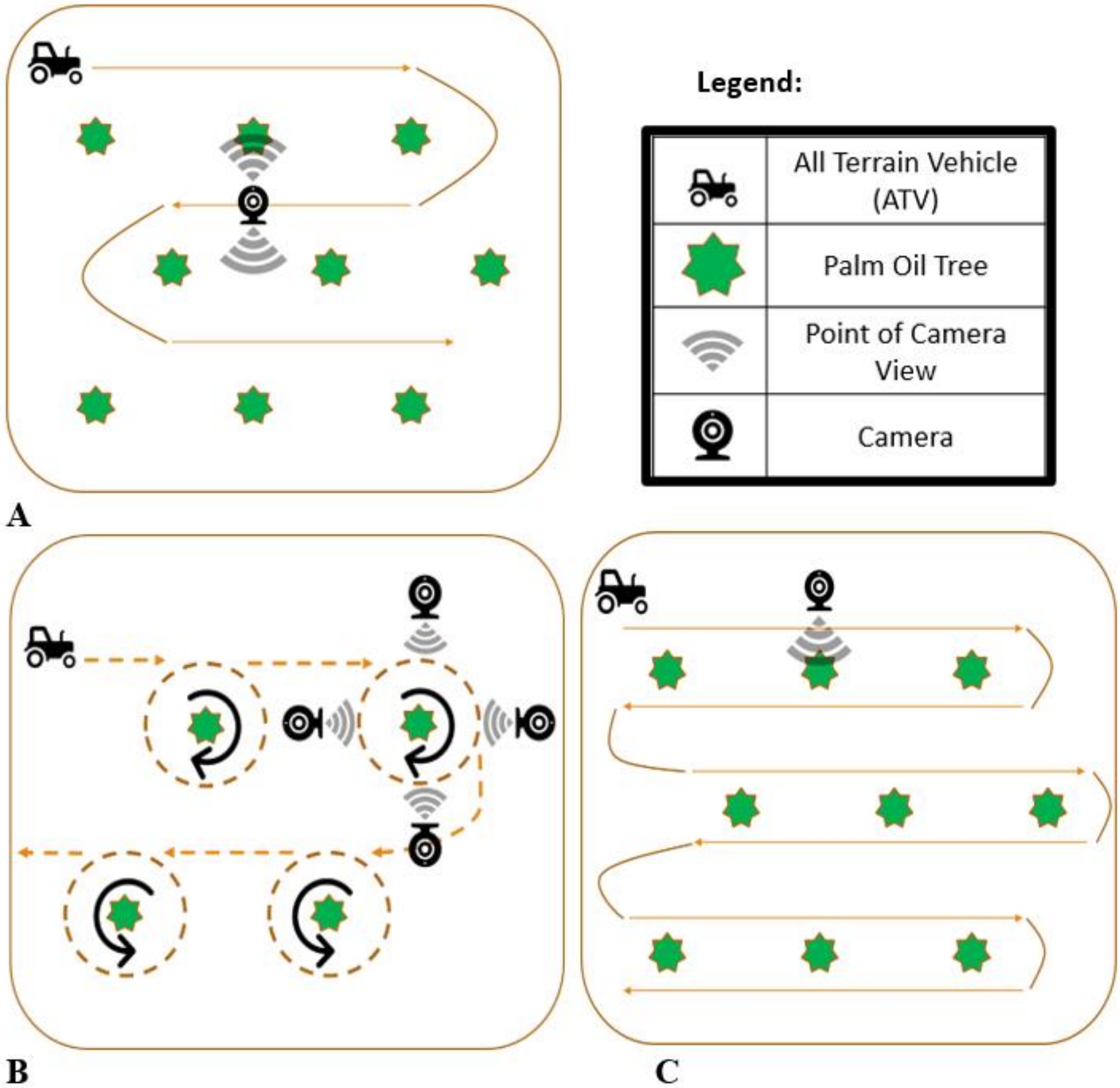

Figure 3. A) Method 1; B) Method 2; C) Method 3

the waves transmitted from the range sensor will be reflected back in a shorter time since there is a tree present in front of the range sensor. Thus, shorter time waves travel between sensor and tree indicates that there is an obstacle in front of the range sensor. Based on the results on the data from the range sensor, image extraction was done only by extracting images that only involve the figure of tree. The data will be stored in folders named according to tree number. This will ensure that images extracted are stored in orderly manner to ease the image processing.

Images of tree were segmented into several parts as shown in Figure 4. Each tree was segmented into 6 views angled at 60°, where each view represents one image extracted from the video stream. As shown in Figure 4, the first Image (a) covered the first 60° angle followed by Image (b) which covered angle between 60° to 120° and the third image labelled Image (c) covered angle between 120° to 180°. The same principle applied for the image extraction on the other side of the tree where Image (d) covered image from 180° to 240° angle of the tree followed by Image (e) which covers angle between 240° to 300° while the last image covers angle between 300° to 360° labelled as Image (f). Three selected images will be taken from each side of the tree.

Since the ATV is not moving with a constant speed, the start and end time every time the camera passes a tree was identified for the extraction of images can be done only for the specific targeted tree. Within the range of the start and end time, three images were extracted for each side of tree in all different angle where the bunch can be seen for bunch identification. Three images on the other side of the tree were extracted which makes total of images collected for one tree is eighteen images from various angle of each tree. The stored image will be further processed for bunch identification.

2.4 Image Processing Technique Using Color Threshold

Images of trees were threshold using threshold tools in the MATLAB software. Threshold is a technique of pixel segmentation based on color space intensity value. After the image extraction was done, 90 selected sample of images were used to be analyzed for the bunch identification process. For the development of image processing model using L*, a*, and b* color space for bunch identification, Image threshold was done using image processing technique using L*, a*, and b* color space. L*, a*, and b* color space was chosen for image threshold since the color space that lies in L*, a*, and b* color space was suitable to eliminate the color of unwanted background. The color of FFB may varies where sometimes black and red in color depends on the maturity level of the FFB. Image extracted from the video was loaded into the image processing tools for image threshold process using L*, a*, and b* color space.

The unwanted background will be eliminated so that the majority left in the image is the targeted Region of Interest (ROI).

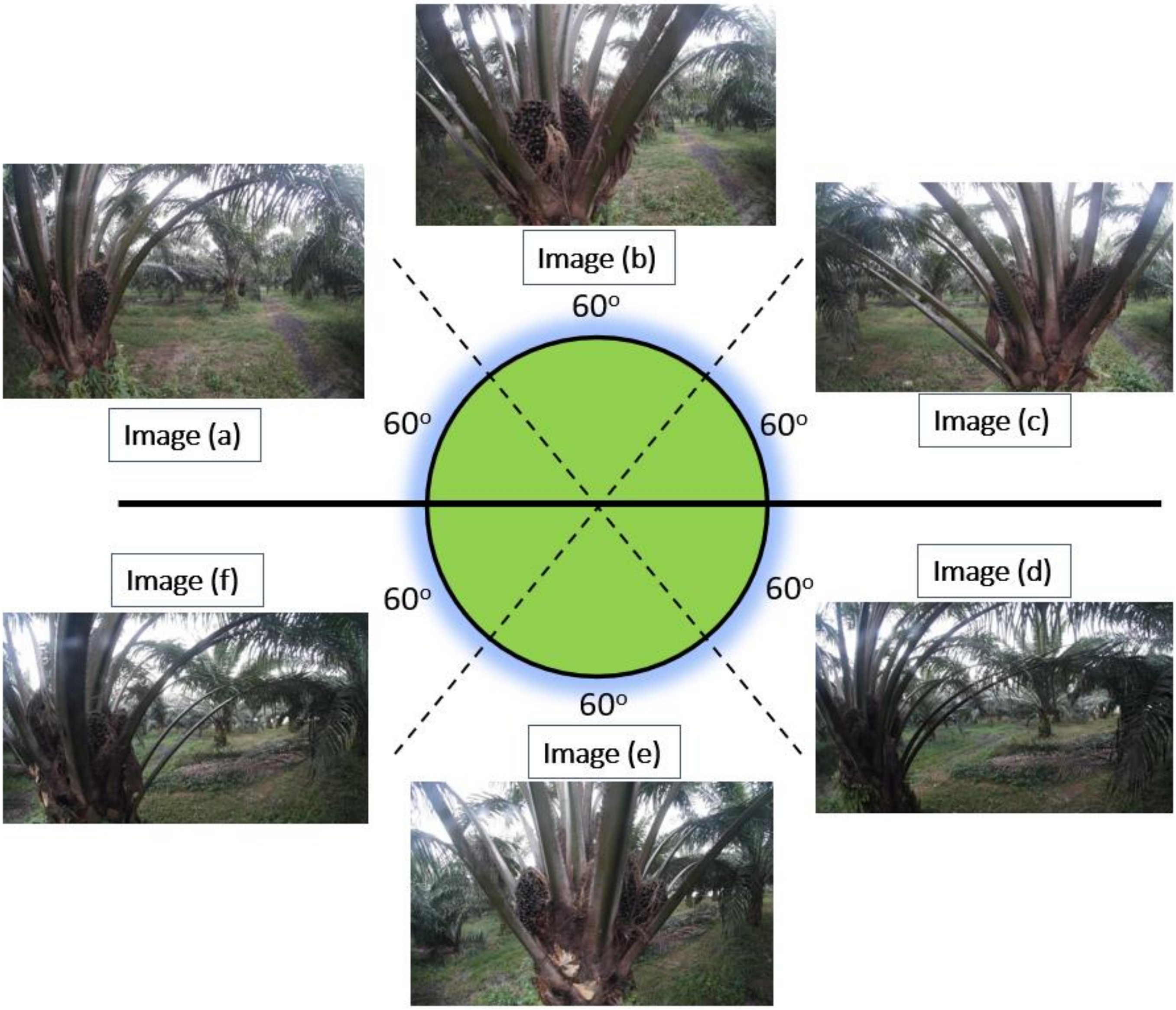

Figure 4. Segmentation of tree for image extraction

Unwanted backgrounds were classified into several elements which are sky which mostly are blue in color, tree fronds and trunk which falls into light brown color, grass, and leaf which majority are in green color. By classifying unwanted background's elements, the figure of bunches can be enhanced and further identified. Eliminating unwanted background instead of identifying the mean value of color of bunches can be useful, since the color of bunches may vary based on the maturity of fruits.

3.0 Results and discussions

3.1 Moving Pattern of ATV for Video Acquisition

The selection of ATV's moving pattern has been determined based on the advantages and disadvantages of each moving pattern as shown in Table 1. Several moving patterns of the ATV installed with camera and sensor has been tested in the plantation area. As mentioned in the methodology section, initially two moving patterns of ATV has been tested for the data collection process of video acquisition. The first moving pattern (Method 1) uses both rear and front lens of the camera to record video while the second moving pattern (Method 2) only uses single lens of the camera to record video. Due to the limitation of the video resolutions, another method of ATV moving pattern was invented which requires the ATV to move closer to each oil palm tree and to move twice in each row as in Method 3 shown in Figure 3(C). This method resulted to a better video resolution, moreover stored video file acquired by using single lens was more manageable and can be easily imported to MATLAB software for further video image processing.

In term of performance wise, shortest time taken and distance travel for the data collection was done by using Method 1 followed by Method 3 and Method 2. Although the time taken and distance travel for the data collection for Method 1 is the best, the video resolutions of data collection by Method 1 is not as best as Method 2 and Method 3. Method 1 video resolution is 2560 x 1440 pixel while for both Method 2 and Method 3 are 3840 x 2160 pixels which is better. For Method 1, both rear and front lenses were used thus programmed by the camera to produce panoramic view video recording which could not be interpreted using MATLAB software. Better video resolution of video and image is helpful for the determination of bunches on each tree for further bunch counting process. Based on the limitations and advantageous of each moving pattern of ATV, Method 3 was selected as the moving pattern since the video taken can be directly imported since the resolutions of the video

Table 1. Advantage and disadvantage for each moving pattern for ATV data acquisition

Method	Advantages	Disadvantages
Method 1	● Use both front and rear lens of the camera. ● Less travel distances to cover whole plantation area. (250 meters for total of 20 trees) ● Less time consumption to complete the whole plantation area. (10 minutes for 20 trees)	● Low video resolution 2560 x 1440 pixel ● Low image resolution. ● Could not be imported into MATLAB due to unsupported format. The format for using both lenses to make a panoramic view which makes the resolution of the video could not be interpreted by MATLAB.
Method 2	● Better video resolution (3840 x 2160 pixel) ● Better image resolution. ● Can be imported into MATLAB	● Only uses one side of lens of the camera. ● More travel distance to cover the whole plantation area. (450 meters for total of 20 trees) ● Take a longer time to cover the whole plantation area. (20 minutes for 20 trees) ● Big data usage for storage. ● Bigger challenge for driver to handle ATV.
Method 3	● Better video resolution (3840 x 2160 pixel) ● Better image resolution. ● Can be imported into MATLAB	● Only uses one side of lens of the camera. ● More travel distance to cover the whole plantation area. (350 meters for total of 20 trees) ● More time consumption to cover the whole plantation area. (15 minutes for 20 trees)

recorded using only one lens of the camera. Method 2 was not selected since it is time consuming for ATV to circle each tree.

3.2 Analysis of Ultrasonic Sensor Data and Image Extraction

Based on the capabilities of this sensor, it is suitable for this project since the distance between tree and ATV is 1 to 1.5 m. The data collected from the ultrasonic sensor is in form of digital data which shows specific timestamp for each detected tree. Output data from ultrasonic sensor includes the timestamps and distance was extracted in a form of table for image extraction analysis. As mentioned in the methodology, the sensor's transceiver is parallel with the lens of the camera. Thus, the distance between the camera and the tree can be accurately measured.

Video recorded from the camera has been imported in the MATLAB software together with the data collected from the ultrasonic sensor. Based on the data collected from the ultrasonic sensor, the process of determining the timestamp where the image with tree is more accurate. The targeted image frames were determined according to the ultrasonic sensor data when the sensor sends signals which indicates the presence of tree within the recorded timeframe.

3.3 Identification of Bunches Using L, a*, and b* Color Space.*

Initially the image acquired are in RGB format since it was captured using optical camera. The RGB image then was converted into L*, a*, and b* color space for image threshold process. The final output of the video was converted back into RGB color space which unwanted background colored with white thus only the figure of FFB remains on the tree crown as shown in Figure 5. As a result, the average range mean threshold value was generated based on the threshold image for each L*, a*, and b*.

Three means of L*, a*, and b* color intensity values were determined in this research. The mean color intensity value of L*, a*, and b* for 90 images are 13.161, 0.316, and 0.752 respectively taken from 15 different trees. The mean value color intensities of L*, a*, and b* were applied in the image threshold for model verifications.

3.4 Image Verification Model Analysis

For model verification, the mean value of each color space of L*, a*, and b* were applied in the code for the image threshold process for the FFB identification for each tree crown. A syntax was developed referring to the function exported from the image threshold process. Thy syntax involved the process of loading each image into the image processing software for verification to undergo image threshold process using the mean range L*, a*, and b* intensity value. For image verification, 48 images were extracted from 8 oil palm trees to test whether the mean value is valid to be applied to other images for the elimination of unwanted background to identify bunches.

All 48 images taken were loaded into the programming software for threshold process based on mean L*, a*, and b* color value intensity done in the analysis previously. The output from the model was paired side by side with the RGB image for better comparison as shown in Figure 5 to identify if the bunch counted in the model image threshold is exactly the same with the original RGB image. The purpose of image verification is to verify the efficiency of model threshold generated from analysis done previously using mean of L*, a*, and b* color range intensity value. Counting of FFB process was done using visual observation from the output image produced from the model threshold.

After considering all aspects of shape and bunch characteristic of FFB, there were 3 visible bunches in the model threshold image without any block from fronds or leaves. The circled bunches on Figure 5(B) indicates the number of bunches that were visible in the model image threshold for bunch counting. By referring to the original RGB image in Figure 5(A), there were also 3 clear bunches that were visible on the tree crown. Which means that the model generated from the analysis is significant and can be used for further image threshold since the number of bunches visible on both images are the same.

Graph in Figure 6 shows the distribution of data of bunches that were visible in both original RGB and model threshold for all 48 images. Both data of original RGB against model threshold images were plotted based on visual observation counting of FFB considering all the characteristic of FFB as mentioned previously. Based on the distribution of FFB number data shown in the graph, there are several model thresholds images that gives the same bunch amount number as the original RGB while several images resulted in different number of FFB count between original RGB and model threshold image.

The straight line is basically a general function f(x) of the straight-line equation generated from the plot distribution which indicates the number of FFB count for both original RGB and model threshold images. Based on the best fit straight-line function generated, the value of Coefficient of Determination, R^2

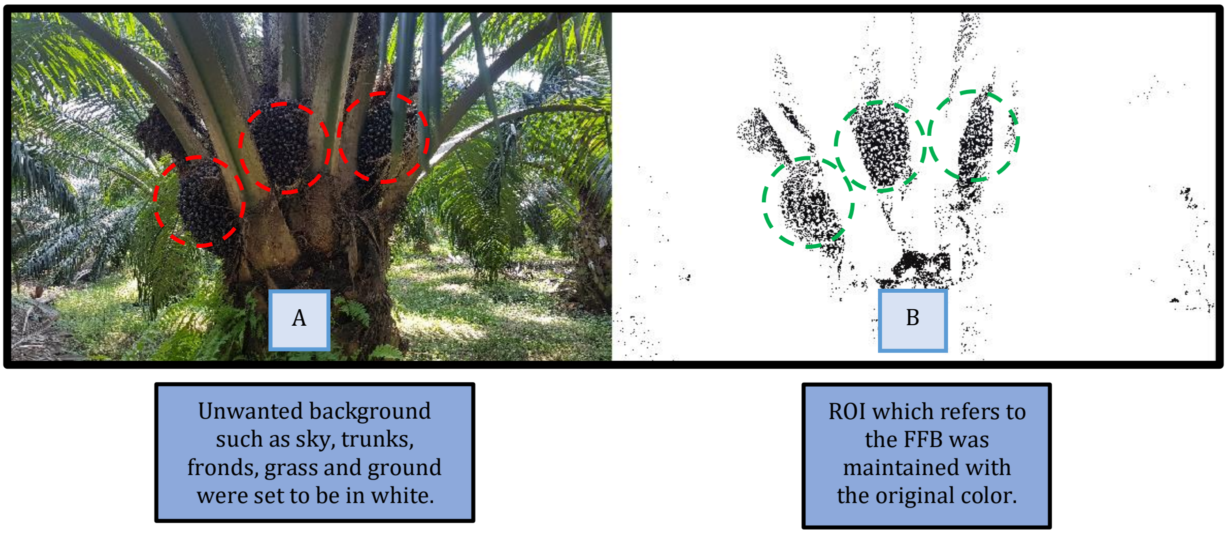

Figure 5. A) Original RGB Image; B) Clear visible FFB in model threshold image output

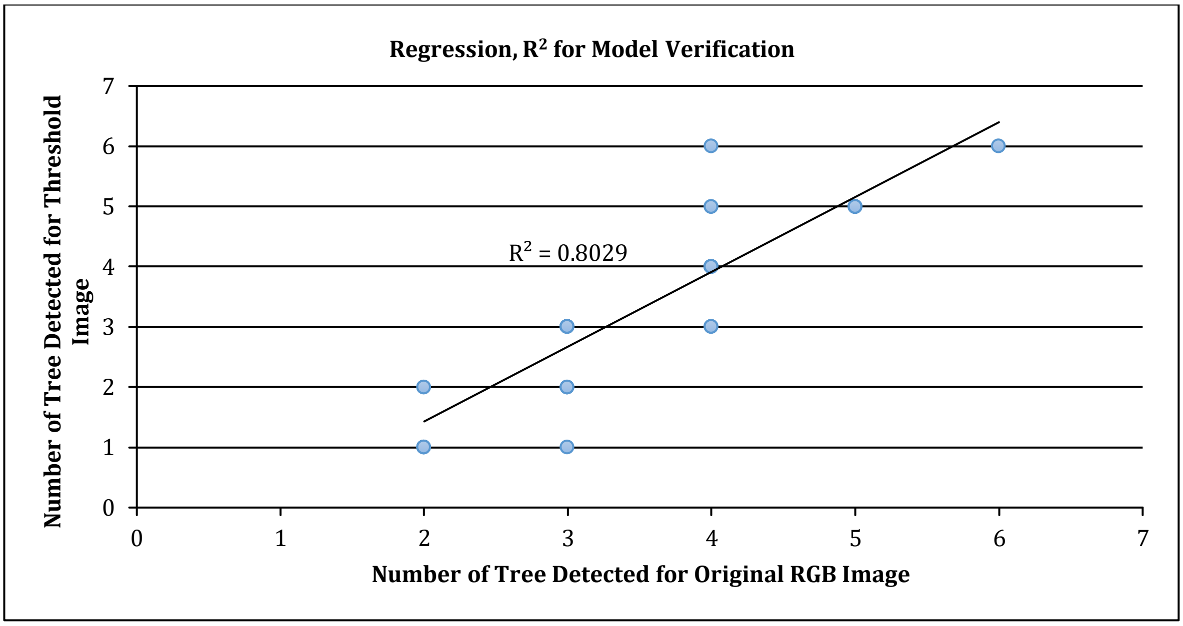

Figure 6. Data distribution of FFB counting between original RGB and model threshold image

value can be determined based on the plot distribution to measure the variation of a dependent variable explained by the independent variable in a regression model. R^2 measures the strength of the relationship between the model and the dependent variable on a convenient 0–1 scale. R^2 is a measure of how well the least equation is. The higher the R^2 the more useful the model. Based on graph, the value of R^2 is 0.8029 which means more than half of the plot distribution are completely explained by the movement of the index. As a result, the model generated from the analysis made can be used for image threshold to eliminate the unwanted background thus enhancing the figure of FFB from every angle of the tree crown to identify the number of FFB.

4.0 Conclusions

The implementation of this technology is suitable and have a potential for large plantation scale. The manual bunch identification method is time consuming and tedious process due to the height of the oil palm tree and position of the oil palm bunches. In line with the demanding for fast and efficient data collection and processing techniques, this rapid imaging system introduced to a new data management procedure to increase productivity to be implemented in plantation.

To conclude, this project is enhancing a new technology of 360° view image to simplify the method of data collection for the identification of FFB on each tree instead of using manual counting using naked eye. Development of 360° view imaging system was done for data acquisition in oil palm plantation area. ATV was used as the mobile platform for data collection in the oil palm plantation area. ATV was installed with mounting as a platform for other components such as optical sensor, ultrasonic sensor, and spotlight in data collection. Optical sensor used in this research is Samsung 360 Camera since the resolution of video and image generated from this camera suite the requirement for the image processing. In order to fulfill the requirement of the image processing, several moving pattern for data acquisition were tested in this research. Three moving patterns for ATV were tested and only one moving pattern which is Method 3 was selected since the video taken using this pattern fulfilled the requirement for the video processing in the processing software. Besides that, the image extraction from the video taken from Method 3 is the most suitable for the detection of FFB for the image processing. Image extraction was done based on the data collected from ultrasonic sensor.

For analysis of image, 6 images were extracted from each tree which can cover the whole 360° view for one tree. Image extracted will be threshold by using MATLAB software. Mean value of L*, a*, and b* for each image extracted will be analyzed for bunch identification. In order to determine the figure of FFB, unwanted background such as sky, fronds, trunks, leaves, and grass need to be eliminated thus leaving the color of FFB in the image to identify FFB.

Three means L*, a*, and b* color intensity values of group determined in this research. The mean L*, a*, and b* color intensity value throughout 90 images from 15 trees are 13.161, 0.316, and 0.752 respectively. For image verification, 48 images were extracted from 8 oil palm trees to test whether the mean value is valid to be applied to other images for the elimination of unwanted background to identify bunches. FFB counts from original RGB and model threshold images were compared for verification of model. The proposed model was applicable to identify the figure of FFB in every image with Coefficient of Determination, R^2 of 0.8029.

360° view imaging system for bunch counting could further improved in certain aspects for better efficiency and accurate data. One of the aspects that need to be considered is the data acquisition technique where the moving pattern could be improved by reducing the time taken for video recording. Further tests and experiment could be done by configuring a shorter moving pattern of mobile platform for video acquisition. In order to achieve this, a suitable and modern optical sensor can be used for better video and image quality. Quality of video and image can be improved by using different camera that provide better resolutions and more detailed pixels. Thus, the moving distance of mobile platform could be shortened since data collection can be done by optimizing the usage of both front and rear camera instead of using only one camera to acquire the data.

Acknowledgement

This work was supported by Grant Putra IPS entitled Development of 360 Degree View Imaging Model for Fresh Fruit Bunch Counting (Reference No:GP-IPS/2017/9547600).

Author contributions

Izat Jaris Dzulkifli: Conceptualization, Methodology, Data curation, and Writing- Original draft preparation. Muhamad Saufi Mohd Kassim: Supervision and Project administration, formal analysis, validation, and Investigation.

Conflict of interests

The authors declare no conflicts of interest regarding the publication of this paper

References

Corley, R. (2009). How much oil palm do we need? Environmental Science and Policy. 12(2), 134-139.

Grossetete, M., Berthoumieu, Y., Da Costa, J. P., Germain, C., Lavialle, O., & Grenier, G. (2012, July). Early estimation of vineyard yield: site specific counting of berries by using a smartphone. International Conference of Agricultural Engineering—CIGR-AgEng.

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

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

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.

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

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).

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.

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

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.

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.

