A Comparative Flight Altitude Using Multi-Rotor UAV for Oil Palm Tree Counting

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Abstract. Unmanned Aerial Vehicle (UAV) is a new platform used in various applications such as landslide monitoring, agriculture, mapping, traffic control, mining, and others. In the photogrammetry survey, the use of UAV is cheaper and more effective for 3-dimensional modelling compared with traditional photogrammetry and Light Detection and Ranging (LIDAR). The ability of UAV to acquire data at a different altitude below the cloud coverage and easy to control has made it one of the most popular platforms in surveying applications. The objective of this paper is to count the numbers of the oil palm tree and define the most suitable flight attitude for tree counting based on the different UAV processing software. The study area is located at Felda Laka Temi in Chuping, Perlis. The comparison of flight altitude is 100m and 200m processed in Agisoft PhotoScan and Pix4D Mapper software. The analysis has been done with errors in Standard Deviation and Root Mean Square Error (RMSE) of Ground Control Point (GCP) which are generated using two different software.

1. Introduction
In Malaysia, oil palm was introduced by the British early 1870 as our country has suitable soil and climate condition for the crops. This crop is very useful for many kinds of products such as palm oil, margarine, soap, and others. So, the largest oil palm plantation for commercial started in 1917 at Ladang Tenmaran, Kuala Selangor. In 1960, oil palm plantation has increased in order to reduce economic dependence on rubber and tin [1]. According to [2] the Malaysian government establishes many agencies after independence to encourage economic growth based on the oil palm industry such as Federal Land Development Authority (FELDA) Federal Land Consolidation and Rehabilitation Authority (FELCRA), and others agency.

Oil palm should always be monitored to maintain the production quantity and quality at the high stages. The basic monitoring quantity oil palm yield is based on the number of oil palm trees within the plantation. The number of the oil palm tree is vital in predicting the yield of each palm tree production for every year [3]. Unmanned Aerial Vehicle (UAV) is a new technology that is used for various remote sensing applications such as soil moisture, agriculture, weather, image analysis, and others [4]. This technology also being used to capture aerial images and video recording for many other applications such as disaster monitoring, military, atmosphere research, search and rescue, and others according to...
[5]. Hence, UAV is suitable for this paper in order to capture aerial images of the oil palm tree in order to do the tree counting [3][6]. Therefore, the study of this paper is focused on the comparison of accuracy in different UAV flight altitudes for palm tree counting using DJI Phantom 4 Pro based on different UAV image processing software.

2. Study Area
Figure 1 below shows the area that had been selected as the study area for tree counting using DJI Phantom 4 Pro. The study area that had been selected is oil palm plantation in Perlis with an area of about 12.8 hectares or 31.629 acres. It is located at 6° 30’ 13” N and 100° 21’ 08” E nearby Felda Laka Temin office in Chuping Perlis, a state at the north part of Peninsular Malaysia. Chuping is the hottest part in Malaysia located near with boundary between Malaysia and Thailand. Besides that, Chuping has 22,000 hectares of plantations consist of rubber plantation, oil palm plantation, and the largest sugar cane plantation in Malaysia. The population of Chuping since 2010 until now is about 12,779 people with males 6,580 and females 6,199.

![Figure 1. Location of Chuping Perlis and Oil Palm Plantation](image)

3. Data and Methods
The methodology of this study consists of four phases. The first phase focused on the preparation of equipment and planning for all data. In this phase, the selection of areas, equipment and method to collect the data were identified. The second phase is data acquisition. The process of collecting aerial images is needed to produce an orthophoto. The main data that is required in this study is an aerial image of Chuping oil palm plantation using multi-rotor UAV DJI Phantom 4 Pro, GNSS observation to establish Ground Control Point (GCP) and Verification Point (VP) [3]. These data then need to be processed to produce the Orthophotos, DTM, Contour map, and TIN map. Next in the analysis phase, all the output is compared between the different flight altitude.

3.1. Data collection
Data involved in this study have been collected using the GNSS and DJI Phantom 4 Pro multicopter UAV [8]. For the GNSS method, Trimble R6 and R4 are used for Ground Control Point (GCP) data collection. Table 1 below shows the values of coordinate and height for that GCP [9]. Meanwhile, the aerial images have been captured by UAV with two different altitudes which are 100m and 200m. The total images for 100m altitude are 208 images and 200m altitude are 68 images. Figure 2 shows the images of the DJI Phantom 4 Pro multicopter UAV.
Table 1. GCPs value using the GNSS method

| GCP   | Latitude      | Longitude     | Elevation (m) |
|-------|---------------|---------------|---------------|
| GCP 1 | 6.503824436   | 100.3500640   | 10.868        |
| GCP 2 | 6.503670100   | 100.3522036   | 12.133        |
| GCP 3 | 6.500688067   | 100.3515487   | 11.360        |
| GCP 4 | 6.501319675   | 100.3502415   | 09.965        |
| GCP 5 | 6.501460900   | 100.3495960   | 10.214        |
| GCP 6 | 6.496487006   | 100.3500668   | 10.234        |
| GCP 7 | 6.497283081   | 100.3490287   | 10.129        |

Figure 2. DJI Phantom 4 Pro

3.2. Data image processing
The images were processed using the Agisoft PhotoScan and Pix4D Mapper software. The images have been processed to compute camera position and align photos. The quality of images also has been checked using estimate images quality and all the images are accepted [10]; [11].

3.2.1. Processing workflow using Agisoft Photoscan
Aerial images processing started from aligning the captured photos using high accuracy setting. The image quality was checked to ensure the range are not more than 5cm for the GSD value. Then, the image processing proceeds for a dense point cloud using high accuracy and aggressive depth filtering setting. The build mesh process was started after the dense point cloud process finished. This process was set for height field setting (2.5D) for the surface type and high for face count setting. After the build mesh processing finished, all GCPs from GNSS observation has been loaded onto the image. The coordinate system of the GCP point is in WGS84. The points of GCPs have been adjusted on the centre of the point using the setting of filtered photo by markers. Then, the GCP marking process has been done in the build mesh process. Next, build texture was carried out using Orthophoto for mapping mode and mosaic for blending mode. Then, start to build the DEM using geographic projection based on dense cloud source and continue with build Orthomosaic. Finally, the orthomosaic and DEM have been exported in tiff format. The overall workflow can be shown in Figure 3 below.
3.2.2. Processing workflow using Pix4D Mapper
For the processing in Pix4D Mapper software, the images have been processed using the provided workflows which are Initial Processing, Point Cloud and Mesh, DSM, Orthomosaic, and index. Then, all the images have been inserted in the software. After finished, the initial processing is done to create the alignment on the images. Then, the GCPs coordinates need to be placed at the centre of each point have been adjusted. The point cloud and mesh have been processed and DSM, Orthomosaic, and index have been generated using this software. The DSM and Orthomosaic have been exported in tiff format at the end of processing. Figure 4 shows a summary of the images processing workflow using Pix4D Mapper software.

3.2.3. Tree counting using eCognition software
Basically, eCognition software for tree counting is used Template Matching technique to compare the portion and recognize a similar object in images to other images. According to [3], Template Matching is a technique for detecting objects from images using the object boundary as criteria because the boundary cloud did not overlay caused by images distortion. By using the algorithms in Template Matching technique, it can identify an area or object within a larger image that matches a specific and smaller template image. Thus, the algorithms will measure the similarity between image and features. Therefore, the calculation of cross correlation between template and image is needed for Template Matching using the squared Euclidean equation as shown below.
Both orthomosaic images generated by Agisoft PhotoScan and Pix4DMapper have been processed in the eCognition software using Template Matching technique. The first step is to select the sample on the images based on the oil palm crown. The sample of the template was randomly selected at the centre of the oil palm crown in the image and generate a template to define the value of the threshold. Select a certain area on the images, test the template using the value of the threshold, and check either the template true or false located at the centre of the oil palm crown.

The point generated on the image has been done after the Template Matching process using the Chessboard Segmentation. Chessboard Segmentation is used to split the image into a square object with size has been predefined in this process. The Template Matching has been duplicated in the Chessboard Segmentation to split one image into two images. Therefore, the image colour has been changed and becomes blue and the vector data has appeared as a point on the crown of the palm tree. The vector points have been generated using eCognition is shown in Figure 5.

![Figure 5. Generated points on the image](image)

3.2.4. Generate the number of oil palm tree
After the process done in the template matching, the output has been used in the ArcMap. In the ArcMap, the number has been generated automatically in the shapefile (.shp) format. The shapefile has been imported in the ArcMap and the number of oil palm tree displayed using the attribute table. The accuracy of the number has been evaluated using the formula below.

\[
\{1 + \left[ \frac{\text{automated count} - \text{ground truth observation}}{\text{ground truth observation}} \right] \}\times 100
\] (4)
4. Discussion and Analysis

4.1. Assessment of Ground Control Point (GCP) Error for both software in 100m and 200m flight altitude

Based on Figure 6 (a), the result of errors for coordinate has been produced for a flight altitude of 100m in both software, Agisoft PhotoScan and Pix4D Mapper. The result shows that the 100m altitude for Agisoft PhotoScan is more accurate compared to Pix4D Mapper. The standard deviation of Agisoft PhotoScan for X, Y, and Z coordinate is 0.823cm, 0.878cm, and 1.669cm respectively. While, the result of the standard deviation of Pix4D Mapper for X, Y, and Z coordinate is 1.110cm, 1.550cm, and 1.450cm respectively. The ranges of error in 3-dimensional coordinate for Agisoft PhotoScan are starting from -0.718cm to 0.844cm for the X coordinate, -0.991cm to 0.881cm for Y coordinate, and -1.939cm to 2.366cm for Z coordinate. For Pix4D Mapper, the ranges of errors for each GCP are -2.700cm to -0.100cm, -2.500cm to 0.900cm and -2.800cm to 1.600cm for X, Y, and Z coordinate respectively. To compare, Figure 6 (b) shows the values of standard deviation errors that have been derived from the mathematical formula for flight altitude 200m. Standard deviation errors 200m flight altitude for Agisoft PhotoScan is 1.647cm, 0.941cm and 3.239cm for three-dimensional coordinate. While, the Standard deviation errors 200m flight altitude for Pix4D Mapper is 1.905cm, 2.512cm, and 2.955cm for coordinate X, Y, and Z respectively. All the RMSE values are according to the means values of the GCPs.

![Figure 6 (a). RMSE for 100m altitude](image1)

![Figure 6 (b). RMSE for 200m altitude](image2)

4.2. Tree counting of Oil Palm Tree

The number of oil palm tree has been derived from the tree counting process using the eCognition software. There are different numbers of oil palm tree detection using four orthomosaics images (two from Agisoft and two from Pix4D). The numbers of oil palm tree derived from Agisoft PhotoScan orthomosaic is higher compared to the Pix4D Mapper orthomosaic. The numbers of oil palm tree detection in Agisoft PhotoScan are 1,812 and 1,773 for 100m and 200m orthomosaic respectively. While oil palm tree numbers detection in Pix4D Mapper is 1,756 and 1,690 for 100m and 200m orthomosaic respectively. By referring to the algorithm in 3.2.4, the differences in numbers of oil palm tree based on the Agisoft PhotoScan is 60 and 99 trees for 100m and 200m. Meanwhile, the differences in numbers derived using Pix4D Mapper output is 116 and 182 trees for 100m and 200m. Hence, the numbers of oil palm tree detected using the Agisoft PhotoScan output is more accurate compared to Pix4D Mapper output. The details are shown in Table 2.
Table 2. The numbers of Oil Palm Tree

| Software       | Agisoft Photoscan | Pix4D Mapper |
|----------------|-------------------|--------------|
| Flight Altitude| 100m              | 100m         |
|                | 200m              | 200m         |
| Observation Number | 1,812          | 1,756       |
|                | 1,773             | 1,690       |
| Actual Number  | 1,872             | 1,872       |
|                | 1,872             | 1,872       |
| Different      | 60                | 116         |
|                | 99                | 182         |
| Percentage (%) | 96.79             | 93.80       |
|                | 94.71             | 90.27       |

4.3. Orthophoto map
The output data is extracted as an orthophoto map. It has been transformed from WGS84 to Kertau RSO. The scale in the orthophoto map is 1:7000 for 4 orthophotos that were produced by both software. Figure 7 shows an orthophotos map for 100m and 200m altitude using Agisoft PhotoScan software. Meanwhile, Figure 8 shows an orthophotos map for 100m and 200m altitude using Pix4D Mapper software.

Figure 7. Orthophoto Map for 100m and 200m altitude using Agisoft PhotoScan software
5. Conclusions
In conclusion, the flight altitude is an important parameter that must be considered when acquiring an image using Unmanned Aerial Vehicle (UAV). The result is proven that the accuracy of 100m altitude more accurate compared to 200m altitude. Next, the comparison between different software which is Agisoft PhotoScan and Pix4D Mapper has been carried out to analyze the acceptance of their product. Based on the analysis of the values of RMSE provided, the output from Agisoft PhotoScan is more accurate compared to the output from Pix4D Mapper. Therefore, the tree counting by eCognition software using Template Matching technique has shown that the number of the trees generated from orthomosaic for both different flight altitude from Agisoft Photoscan output has produced a better result compared to the output from Pix4D Mapper.

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