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The Development of a 3D Model of Oil Palm Fresh

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Abstract: Terrestrial Laser Scanner (TLS) is widely used to generate a 3-Dimensional (3D) Model from point cloud data. TLS technology can produce precise 3D Model rapidly. In this study, a new method for Fresh Fruit Bunch (FFB) mass estimation is developed by constructing its 3D Model using point cloud data obtained via. TLS and three software for data processing, namely SCENE, CloudCompare and MeshLab. Suitable setting parameters for data acquisition were identified to be 2 m distance from the oil palm tree and 6.31 min of scanning time. Three different sets of temporal scanning were conducted, i.e., 2 days before harvesting, 14 days before harvesting and 17 days before harvesting. The mass of FFB was estimated using the equation, mass (kg) = 875.30*3D volume. Results showed an average difference of 1.24-2.00 kg between the weighted and calculated values. Additionally, a smaller difference (1.24 kg) was shown for data collected 14 days before harvesting, compared to data collected 2 days (1.89 kg) and 17 days (2.00 kg) before harvesting.

Key words: Point cloud, 3D, modeling, oil palm, weight, SCENE

INTRODUCTION

Volume estimation is useful for determining physical characteristics of the fruits such as mechanical damage of fruit due to external force, the shiftiness and predicting the surface injury. Meanwhile, converting real trees into a 3D computer representation is affected by the low quality of the reconstructed point cloud and the inaccuracy of the skeletonization process due to the complex structure of trees (Zhang *et al*., 2016). A critical part in developing a 3D Model lies in the filtering process, whereby the point cloud has to be sampled (Madhusudan, 2016) in order to produce the best fit geometry based on the purpose (Pujari *et al*., 2017). Corsini *et al*. (2012) used the Poisson-disk sampling method to generate a customized set of point which can be modified easily such as essential sampling or distribution.

TLS is one of the available techniques to create a 3D Model and has become a valuable tool for assessing vegetation structure (Bejo and Vong, 2014) due to its capability to provide objective and consistent, though not necessarily unbiased measurement. TLS offers the benefit of extracting structural metrics which cannot be measured cost-efficiently by traditional method such as caliper or tape (Pueschel, 2013). It can detect tree with more than 97% accuracy and determine the Diameter at Breast Height (DBH) to a precision of about 1.8 cm (Maas *et al*., 2008). To improve the characterization of forest canopy with TLS, Zhao *et al*. (2015) performed a methodological paradigm that combines Physics and Statistics to derive the foliage profile, Leaf Area Index (LAI) and Leaf Angle Distribution (LAD). A study on the effect of scan resolution, scan speed, pulse duration and raw data filtering on stem diameter, stem detection and volume extraction from phase-shift TLS data was done in the Pfalzerwald forest near Kaiserslautern, Germany (Pueschel, 2013). This research is important because the demand is to maximize sampling and minimize the cost of forest inventory due to scanning time which can be controlled by scan resolution, scan speed and pulse duration.

While TLS is beneficial in assessing agricultural structure, the use of TLS for volume estimation is still limited, especially for oil palm FFB. Therefore, the study has been conducted with the following objectives: to determine the suitable distance between TLS and oil palm tree during data acquisition; to determine the suitable scanning time and to estimate FFB mass using the volume of the constructed 3D Model.

MATERIALS AND METHODS

Study area and materials: The study site was located at the Universiti Putra Malaysia oil palm plantation. The age of the oil palm trees were between 4-5 years old. The tree

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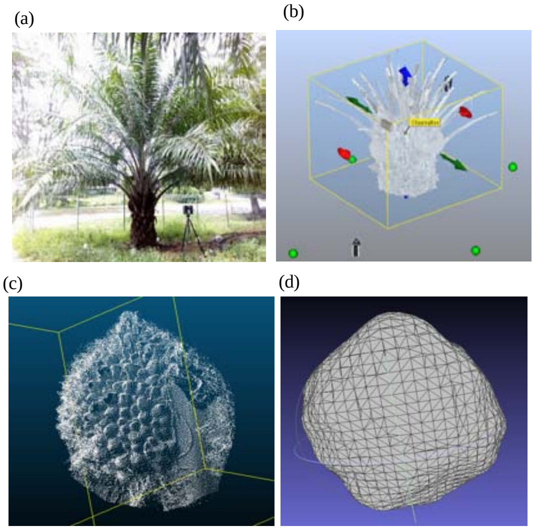

Fig. 1: Process involved to develop 3D image of FFB structure: a) Data acquisition using FARO laser scanner; b) Point cloud registration in SCENE Softwar; c) Point cloud filtering in CloudCompare Software; d) Point cloud meshing in MeshLab Software

Table 1: Total number of harvested FFB on three different dates

Tree ID	18th April 2016	3rd May 2016	21st May 2016	Total
P1	3	1	1	5
P2	1	2	1	4
P3	1	1	1	3
P4	2	0	1	3
P5	4	1	1	6
Total no. of harvested FFB	11	5	5	21

is of dwarf-typed for ease of harvesting. The FFB type is Nigrescens, whereby the young exocarp is green and matures into orange with brown or black cheek. Data collection was done on three different dates as detailed in Table 1. The ID for each tree is in the form of Pa(b), whereby a is the tree ID and b is the FFB ID. The total number of harvested FFB was 21.

Development of 3D Model of FFB structure: There are four stages in developing the 3D FFB Model, namely data acquisition, point cloud registration, data filtering and data meshing. A flowchart of the process is shown in Fig. 1. The detail of each stage is described in the following sub-section:

Data acquisition: The ground around the tree was cleared to ensure that all four balls can be clearly seen. In this research, two distances between the FARO laser scanner and the oil palm tree were tested which were 2 and 3 m. The resolution which was defined by scanning time was fixed at three different resolutions which were 3.05, 6.31 and 9.06 min. The point clouds were stored automatically in an SD memory card.

Point cloud registration: Point cloud registration was done using the SCENE (V5.2, US) Software which was the processing software for the FARO laser scanner. SCENE 5.2 is a high performance 3D Point Cloud Software. It processes and manages scanned data easily and efficiently by using automatic object recognition as well as scan registration. For each tree, the scan images taken from four different angles were inserted into the software in a new scan project. All four scans were viewed via 'Quick View', 'Find object' operation to search for the reference sphere. The sphere must have the same label for every angle to be detected. After that, the 'Registration' operation was carried out to register the scan. After the registration process was completed, a clipping box was created to select the oil palm tree. Then, unwanted points (hereafter, referred as noise) were removed using the CloudCompare (V2.6.1) Software. The clipping box was exported as 'xyz' file for further analysis.

Data filtering: CloudCompare was used as a filtering software to remove the noise at the tree. The FFB on the tree was selec ted using the cross section function in software. Then, the selection was exported as a new point cloud. The segment function was used to remove the unwanted points. The new cloud was saved in 'ply' format as it is compatible with the MeshLab Software.

Data meshing: MeshLab (V1.3.3) Software was used to mesh the filtered point cloud. It is an open source software which can be used to process unstructured 3D triangular meshes. First, the dataset was subsampled in order to have more manageable dataset and faster computation. The Poisson disk function was used to filter the point cloud.

Harvested fruit weighing: The FFB weight was recorded upon harvesting using a digital weighing scale which has four load sensors (strain gauge). The weighing scale was put on a small table on a flat and stable position as it is very sensitive to uneven surface.

Mass estimation: Equation 1 was used to estimate the mass of FFB based on its 3D volume. In this study, different density values were tested by referring to values given by Mohd and Shariff. The value which resulted in the smallest difference between the weighted and calculated values was used to estimate the mass:

$$\text{Mass, m(kg)} = \text{Density}\left(\frac{\text{kg}}{\text{m}^3}\right)\times\text{Volume, V}(\text{m}^3) \quad (1)$$

RESULTS AND DISCUSSION

Distance between TLS and oil palm tree during data acquisition: results from the independent sample t-test (Table 2) showed significant difference between 2 and 3 m distances during data acquisition where ($p<0.005$). Table 3 shows the results of group statistics. Based on this results, the average, the standard deviation and the standard error mean for the 2 m distance was <3 m distance. Based on these results, it can be concluded that 2 m is the preferable distance for scanning which provides more acceptable accuracy and lower error.

Scan time: ANOVA results showed no significant difference ($p>0.05$) in the FFB volume for each scan time, i.e., 3.05, 6.31 and 9.06 min. In order to support the ANOVA result, a multiple comparison analysis (Turkey HSD) was done as shown in Table 4. All results showed significant value of ($p>0.05$), indicating there was no difference between the scanning time. As a result, 6.31 min was selected as the preferred time. The shorter scanning time was not chosen because it resulted in inaccurate points for meshing while 9.06 min was too time consuming.

Mass estimation: Table 4 shows the difference between the estimated mass and weighted mass based on different densities. Higher density resulted in higher difference between the weighted and estimated FFB. The density value of 875.30 kg/m^3 resulted in the lowest difference between the weighted and estimated FFB. Therefore, 875.30 kg/m^3 is best used to estimate the FFB mass using the volume of the 3D Model. Meanwhile, data recorded at 14 days before harvesting gave better mass estimation for all tested densities. This was followed by 2 and 17 days after harvesting. Results also showed that the accuracy of the estimated volume of FFB without frond obstruction was higher compared to that with frond obstructions. As shown in Fig. 2, FFBs with one frond obstruction had more accurate result compared to those with two frond obstructions. In summary, the best mass was estimated using data without frond obstruction recorded at 14 days before harvesting with 875.30 kg/m^3 density value. It resulted in an average difference of 1.24 kg and a standard deviation of 0.84 kg.

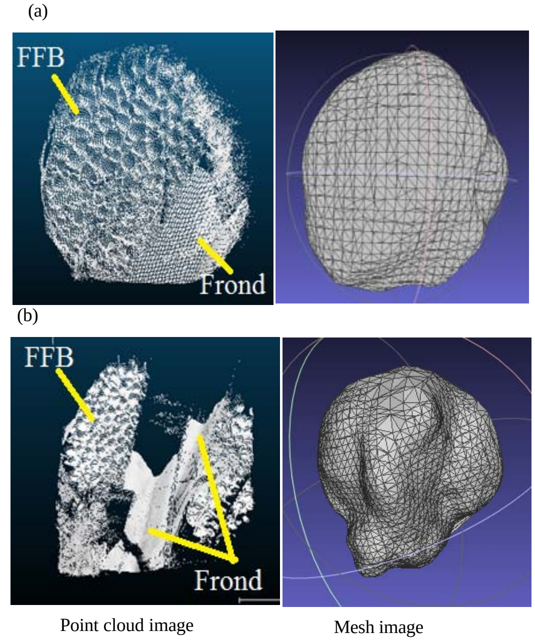

Fig. 2: The image of FFB: a) With 1 frond obstruction, estimated mass (kg): 10.07; real weight (kg): 11.00; frond obstruction: 1 and b) With 2 frond obstructions; estimated mass (kg): 23.70; real weight (kg): 11.00; frond obstruction: 2

Table 2: Independent sample t-test

	Levene's test for equality of variances		t-test for equality of means	
Volume	F-value	Sig. (p)	df	t-values
Equal variances assumed	10.958	0.002	64	-1.530
Equal variances not assumed			34.083	-1.530

Table 3: Group statistics

Distance (m)	N	Mean	SD	SE mean
Volume				
2	33	0.020	0.020	0.003
3	33	0.050	0.111	0.019

Table 4: Multiple comparison (Tukey HSD)

(I) Time	(J) Time	Mean difference (I-J)	SE	Sig. (p)	95% confidence interval Lower bound	Upper bound
3.05	6.31	0.002	0.025	0.995	-0.057	0.062
	9.06	-0.001	0.025	1.000	-0.060	0.059
6.31	3.05	-0.002	0.250	0.995	-0.062	0.058
	9.06	-0.003	0.250	0.992	-0.062	0.056
9.06	3.05	0.001	0.250	1.000	-0.059	0.060
	6.31	0.003	0.250	0.992	-0.056	0.062

Table 5: Average and standard deviation of the difference between weighted and estimated FFB at different density

		Average and standard deviation of the difference between weighted and estimated FFB taken from all data		Average and standard deviation of the difference between weighted and estimated FFB without frond obstruction	
Density (kg/m^3)	Days before harvesting (days)	Average (kg)	± SD (kg)	Average (kg)	±SD (kg)
920.00	2	3.50	3.08	2.51	2.46
	14	2.00	1.28	1.80	0.88
	17	4.94	5.24	2.61	0.74
910.00	2	3.35	3.05	2.37	2.43
	14	1.87	1.27	1.67	0.87
	17	4.78	5.18	2.48	0.73
900.00	2	3.20	3.01	2.23	2.40
	14	1.75	1.26	1.54	0.86
	17	4.61	5.12	2.34	0.72
890.00	2	3.05	2.98	2.09	2.37
	14	1.62	1.25	1.42	0.85
	17	4.45	5.07	2.20	0.71
880.00	2	2.90	2.95	1.95	2.34
	14	1.50	1.24	1.29	0.84
	17	4.29	5.01	2.06	0.70
875.30	2	2.84	2.94	1.89	2.33
	14	1.44	1.24	1.24	0.84
	17	4.22	4.98	2.00	0.69

CONCLUSION

From the study, it can be concluded that the point cloud obtained using TLS can be used to develop a 3D Model of FFB on trees. Four main stages were involved in developing the 3D Model using three types of software: data acquisition, point cloud registration (SCENE Software), data filtering (CloudCompare Software) and data meshing (MeshLab Software). The suitable parameters to scan each tree is 2 m distance between TLS and oil palm tree with 6.31 min scanning time, resulting in a total of 30 min for a complete scan for four different angles (including the time taken to set up the equipment). The results of the temporal scanning showed a smaller difference in average between weighted and estimated FFB (1.24 kg) at 14 days before harvesting, compared to 2 days (1.89 kg) and 17 days (2.00 kg). The standard deviation of the difference between the weighted and estimated FFB ranged between 0.69-2.33 kg. The accuracy of the estimated volume of FFB was affected by frond obstruction. Therefore, FFBs with <2 frond obstructions gave more accurate results compared to that with more frond obstructions. Estimating FFB weight on the tree will contribute to proper management of plantation, especially for post-harvest processes such as fruit transportation, fruit sorting and fruit grading.

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