Relationship of Oil Palm Crown Features Extracted Using Terrestrial Laser Scanning for Basal Stem Rot Disease Classification

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Abstract: The oil palm is the largest plantation industry in Malaysia. It has been one of the major contributors to the country's economy and the main pillar of the commodity sectors. For over 40 years, the oil palm industry has faced a lethal and incurable disease, Basal Stem Rot (BSR), which is caused by a type of bracket fungus, *Ganoderma boninense*. The oil palm physical symptoms infected by BSR disease are appearance of many unopened spears, flattening of crown and smaller crown size. Terrestrial Laser Scanning (TLS, also known as ground-based LiDAR) can be used to provide accurate and precise information on tree morphology with high resolution. This study proposed an image processing technique using the ground input data taken from a TLS. Five parameters were used in the study are number of laser hits in strata 200 cm and 850 cm from the top, namely as C200 and C850, respectively, crown area, frond number and frond angle. The objectives of this study are to analyse the relationship between the parameters and to study the relationship of the parameters with the levels of BSR disease. Results have shown that all parameters were significant in all levels of healthiness with p-values less than 5%. Frond number and frond angle showed the highest correlation value, which is equal to -0.94. Frond angle is increasing, while frond number and crown area are decreasing concurrently with the severity levels of BSR infection.

Keywords: LiDAR, Point cloud, Image processing, Crown strata, Oil palm, BSR.

Introduction

Oil palm is a typical crop of the rainy and humid lands, suitable to be planted in tropical climate countries and mainly grown for its industrial production of vegetable oil. Oil palm is now considered as the most important supplier of vegetable oil in the world (Verheye, 2010). Oil palm industries represent the second largest export product of Malaysia (Sulaiman *et al*., 2011). Malaysia is one of the largest producers and exporters of palm oil in the world representing 11% of world's oils and fats production and 27% of world's export trade of oils and fats (MPOC, 2017). Basal Stem Rot (BSR) is the most destructive disease

of oil palm in South-East Asia, especially in Malaysia. *Ganoderma boninense* is the causal pathogen of BSR disease (Naher *et al*., 2013) with a white rot basidiomycetous fungus. The pathogen infects oil palm primarily through the roots and degrades the lignin component of wood, caused dry rotting at the stem base (Paterson, 2007). The disease progresses slowly but every infected plant usually dies. In the early stages of infection plants usually appear symptomless and the symptoms appeared only when the plant is severely infected, while plants with severe symptoms are unable to be saved.

The main visible symptoms could be discovered at the external part of infected oil palms, especially at the bottom of the trees and the leaves parts (foliar symptoms). Turner & Gillbanks (1974) and Nisfariza *et al*. (2010) found that the foliage symptoms of infected oil palms are the declination and skirt-like shape of crown, unfolded spears, and not well-developed crown size. Fig. (1) shows some severe symptoms of BSR disease which can be seen on the infected oil palm tree. Some diseases related to the palm trees occurred around the world such as in Pakistan (Abul-Soad *et al*., 2015), India (Kandan *et al*., 2010), Philippines (Turner, 1982), Thailand (Pinruan *et al*., 2010), African countries (Mariau *et al*., 1996; Kinge & Mih, 2011), Middle East countries (Djerbi, 1998; Abdelmonem & Rasmy, 2007), USA (Elliott & Broschat, 2000), Caribbean regions (Abad-Franch *et al*., 2005) and in other countries. The detection of all the diseases is still manual (visual) by looking at the external appearances. Looking at the appearance of the symptoms, it shows that the crown and the frond features were heavily affected.
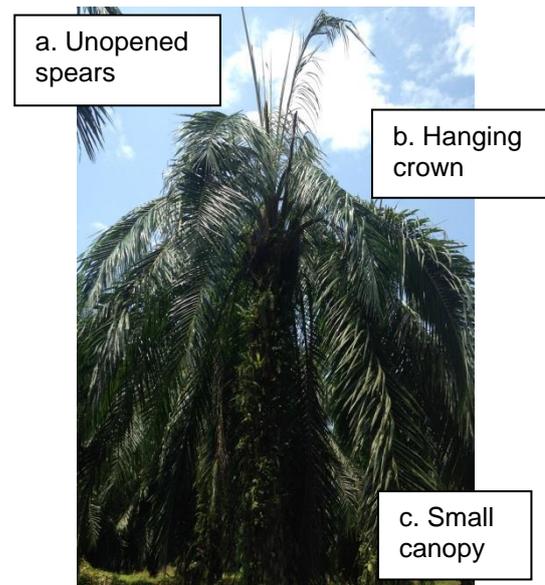

a. Unopened spears

b. Hanging crown

c. Small canopy

Fig. (1): Foliar symptoms of oil palm trees with severe infection of *Ganoderma boninense* (a - c).

Literature review

There is still no specific standard visual symptoms could be used to classify the level of infection, while some researchers have contradicted assessment for the description of the trees to assess the level of infection (Lelong *et al*., 2010; Nisfariza *et al*., 2010). Generally, there are three ways to detect the BSR in oil palm trees i.e., manual method, lab-based and sensor-based. Manual method based on individual or scouts monitoring is labour-intensive, prone to fatigue and low accuracy due to human dependence. Laboratory-based methods are reliable for early detection; however, they are costly, complex, time consuming and ill-suited for outdoor conditions (Naher *et al*., 2013). Multispectral imaging (Santoso *et al*., 2011, Khairunniza-Bejo *et al*., 2015, Bejo *et al*., 2018) and hyperspectral imaging (Lelong *et al*., 2010; Nisfariza *et al*., 2010; Shafri *et al*., 2011; Izzuddin *et al*., 2013; Liaghat *et al*., 2014; Izzuddin *et al*., 2015; Ahmadi *et al*., 2017) techniques can differentiate between healthy and unhealthy oil palm trees with varying

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levels of accuracy. However, these techniques insufficiently discriminate the different levels of severity. Rapid, easy, non-destructive, non-invasive and accurate detection tool is in need since oil palm plantation is cultivated in the extensively wide area (Khairunniza-Bejo *et al*., 2015).

Lidar technology has been used to obtain geometrical attributes of the target and was proven to be a feasible option for modelling three dimensional (3D) features of tree crops (Colaco *et al*., 2017). Terrestrial Laser Scanning (TLS), also known as ground-based LiDAR (Light Detection and Ranging) is an active imaging method which is contact-free, precise, cost-effective and user-friendly contributed to its expanding use. These 3D profiling systems have some features that can provide accurate information about tree dimensions and morphology, which relates to plant development and health, such as high degree of accuracy and precision, up to mm (Campos *et al*., 2014). Recent studies have shown the use of TLS to monitor the plant growth and physiology of plant canopy is promising (Lumme *et al*., 2008; Keightley & Bawden, 2010; Tilly *et al*., 2014; Hoffmeister *et al*., 2016). Based on the literature, it can be concluded that TLS is well-adapted for intensive study of tree geometry in-situ. Yet, there exist very few TLS studies focusing on a fine level of oil palm tree architecture especially on the canopy analysis for disease detection. The first preliminary study on the use of TLS for BSR detection was performed by Khairunniza-Bejo & Vong (2014). The results showed that there were correlations between the oil palm trunk's perimeter, Diameter at breast height (DBH) and canopy area with the BSR disease. This preliminary study supported the potential use of TLS for analysing the properties of oil palm trees to distinguish healthy and infected BSR at

different levels of infection. Recently, Azuan *et al*. (2019) has shown that crown pixel, frond number and frond angle extracted from TLS data gave significant different in classifying BSR and non-BSR oil palm trees. Meanwhile, Husin *et al*. (2020) have developed classification models using selected crown strata and top-down view images for BSR detection. Hence, the previous studies did not incorporate all the significant single parameters for analysing the relationships between the parameters and the order of significant changes that can be seen on the parameters across the severity levels of BSR infection. Therefore, the objective of this research is to study the relationships between the oil palm crown features extracted using TLS method for BSR disease classification.

Materials & Methods

Terrestrial laser scanner

In this study, physical characteristics of oil palm tree were analyzed using Faro Laser Scanner Focus 3D data (FARO Technologies, Inc., Florida, USA). FARO laser scanner uses high-speed laser technology to acquire millions of three-dimensional (3D) laser points for detailed measurement and documentation in significantly shorter time. Since the field of view of Faro Laser Scanner Focus 3D is 360° × 305°, therefore, ground scanning has the capability to scan top view of the tree. Repetition of the single point measurements is up to 976,000 times per second, which results into a Point Cloud (a 3D dataset of the scanner's environment known as laser scan). The laser scan was recorded on a removable SD memory card which then can be transferred to the SCENE software (version 5.0, FARO Technologies, Inc.), which is FARO's point cloud processing software for further analysis.

Data collection

The study area is located at the oil palm plantation in Seberang Perak, Malaysia. The age of oil palm trees is 9 years old while the heights of the trees were range between 10 to 11 meters, where the production is at the peak. The oil palm trees are categorized into four healthiness levels: T0 is the tree without BSR disease, T1 is the mildly infected, T2 for moderately infected and T3 for severely infected BSR disease (Fig. 2). Categorization of the trees is followed by descriptions provided by Malaysian Palm Oil Board (MPOB) as shown in Table (1) (Khairunniza-Bejo *et al*., 2017; Bejo *et al*., 2018). A total of 40 oil palm trees had been selected with 10 trees for each healthiness level randomly taken from several different locations in the same block to minimise the environmental variation effects.
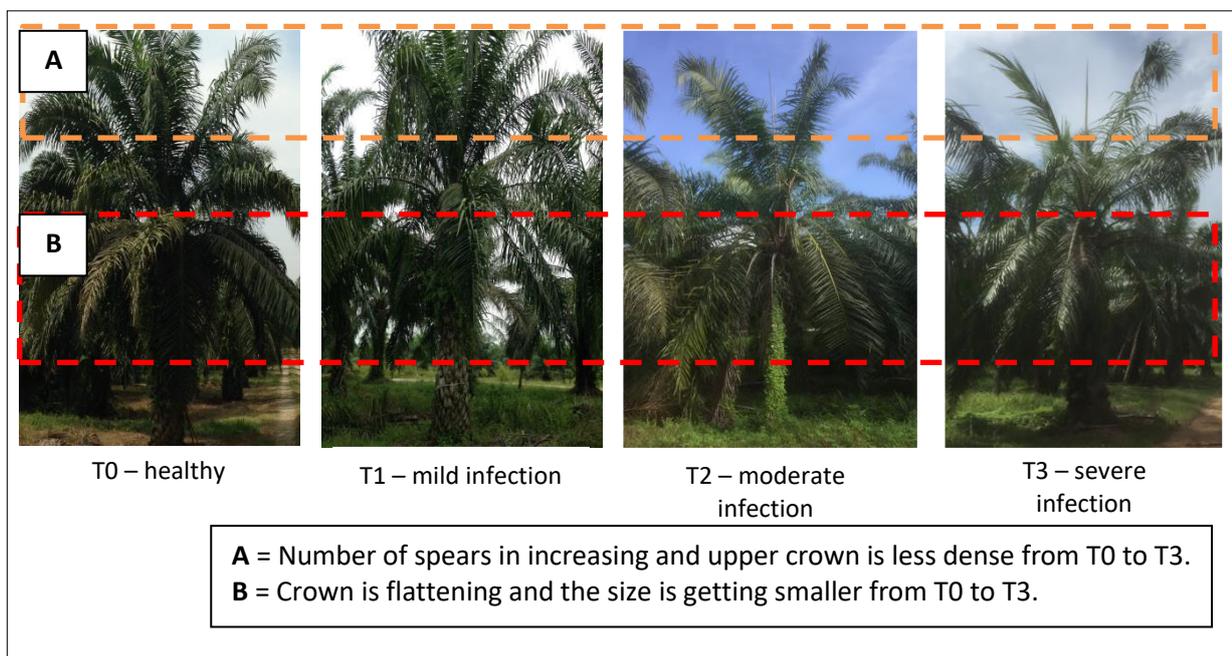

A = Number of spears in increasing and upper crown is less dense from T0 to T3.
B = Crown is flattening and the size is getting smaller from T0 to T3.

Fig. (2): Pictures of oil palm tree based on the healthiness level.

Table (1): Classification and tree descriptions.

Classification	Trees observations
T0	Healthy palm, no foliage symptom (0%), no fruiting body
T1	Mild infection, foliage symptom (1-25%), produce fruiting body
T2	Moderate infection, foliage symptom (26-50%), fruiting body
T3	Severe infection, foliage symptom (>51%) and fruiting body

The data were collected on 7 to 11 of July 2017. The scanner was mounted on a surveying tripod at the height of 1 m and a distance of 1.5 m from the oil palm tree. Tripod

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was placed on firm ground and levelled it using a bubble balancer. Five to eight reference spheres were placed around the tree and each tree was scanned four times from different scan locations around the tree. Spheres were used as a reference in case a problem is found when synchronizing the scanned data.

Data processing

SCENE software (version 5.0, FARO Technologies, Inc.) was used for pre- and post-processing of the laser scans. The scans were processed through the 'registration' step, where four TLS scans were matched for every tree and the laser point data were synced to create a cluster of point clouds and a complete 3D view of the tree. The image of the frond from top view was analysed using AutoCAD software (Autodesk, Inc., San Rafael, USA). 'Polyline' was used to draw the shape of the frond on the image. Next, 'Dimension' tool was selected to determine the distance between each frond (measured in angle). Meanwhile, the area of crown for each tree was determined by counting number of pixels inside the crown image. The details of the steps can be referred to the study by Azuan *et al.* (2019).

The density of the crown strata indicates the thickness of oil palm fronds at various heights. Different values of laser hits in crown strata were used to identify crown strata that can provide significant differences between all severity levels of infection. Stratification method was used to segment the point cloud data of oil palm trees for data reduction (Ayrey *et al.*, 2017). Series of horizontal layers (known as strata) with equal interval and size perpendicular to the vertical direction were created. The thickness of the clipping box was set to 0.1 m and the space between the boxes was set to 0.5 m following Bienert *et al.* (2006) and Lovell *et al.* (2011) (Fig. 3). The details of

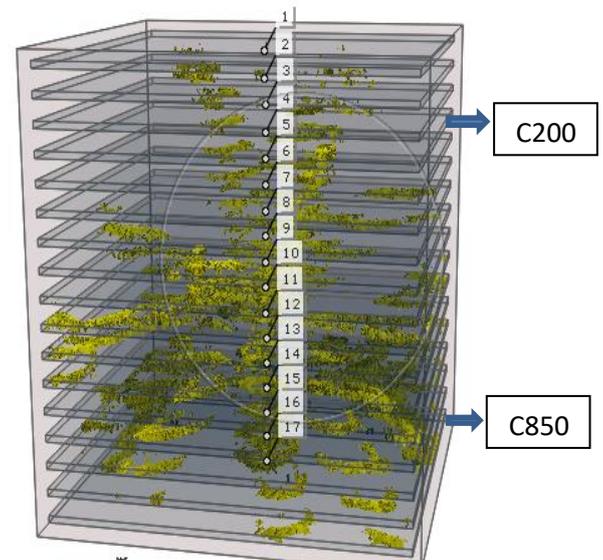the steps can be referred to the study by Husin *et al.* (2020).

Fig. (3): Stratification method.

Oil palm crown parameters

Five parameters were used for the classification models: frond number, frond angle, crown pixel, C200 and C850. C200 is the crown stratum located 200 cm from the top, while C850 is the crown stratum located 850 cm from the top. JMP software (SAS Institute, North Carolina, USA) was used to statistically analyse the data using Kruskal-Wallis test at 5% significance level (α = 0.05). In addition, Microsoft Excel (Microsoft, Washington, USA) was used to calculate the correlations between the parameters.

Results & Discussion

Statistical analysis

Table (2) shows the summary of Kruskal-Wallis test results, where all the parameters showed significant difference between the levels of healthiness at 5% significance level. Crown area, frond angle and frond number presented the lowest p-value, less than 0.01%, followed by C200, with p-value of 0.0166 and

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C850, with p-value of 0.0471. The highest Chi square value was obtained by frond number, 33.428 and the lowest was obtained by C850, 8.058.

Table (2): Kruskal-Wallis test for every parameter.

Parameters	Chi square value	p-value
C200	10.248	0.0166*
C850	8.058	0.0471*
Crown area	23.058	<.0001*
Frond Angle	32.666	<.0001*
Frond Number	33.428	<.0001*

*significant at 5% level

Relationship between the parameters

Table (3) shows the Pearson correlation value for all the parameters namely frond number, frond angle, crown area, C200 and C850. The highest correlation was shown by frond number and frond angle, which is equal to -0.94. It depicts that the lower number of fronds, the larger the angle would be found on the tree. The second highest correlation was shown by frond number and crown area, which is equal to 0.76. It indicates that healthy oil palm trees that have higher number of fronds associate with larger crown area, while unhealthy trees have lower number of fronds relate with smaller crown area. In addition, the correlation between crown area and frond angle, -0.74, which demonstrates that the larger the crown area, more frond number will be found in the tree, which reflects to smaller degree of inter-fronds angle.

The effects of BSR disease to the crown structures are clearly shown in fig. (4). The crown area is reducing parallel with the severity levels of disease infection, which also shown by the number of pixels, decreasing from T0 to T3. *Ganoderma boninense* fungus produces many enzymes that damage the internal part of the oil palm trees lead to nutrient deficiencies, stunted growth and smaller crown sizes. Furthermore, number of fronds is reducing and degree of angles between fronds is increasing concurrent with the severity levels of infection. Healthy oil palm trees show normal growth of fronds. While in infected trees, the fungus had effects on the growth of new leaves, causing more unopened spears and unfolded leaves. Besides, infected trees have fewer fronds due to the slow growth and collapsing of the fronds caused by the infection, and higher pruning to remove hanging fronds in harvesting by the plantation workers. These results relate with the outcomes in table (3), where decreasing number of fronds in infected trees, decrease the area of crown and increase the angle between the fronds.

Conclusions

Based on the results, it can be concluded that the comprehensive laser point data from terrestrial laser scanner could be used to extract physical features of oil palm trees for BSR severity classification. The extracted features namely stratified point cloud at strata 200 cm and 850 cm from the top, crown coverage area, number of fronds and inter-frond angle could be used as parameters to differentiate non-infected and infected oil palm at different severity levels. High correlations were also shown between the parameters. This image processing technique using the input parameters from the ground could be explored for early detection, management and control strategies of the disease. The technique also could be used for in-situ application with support of good pre-processing and post-processing facilities.
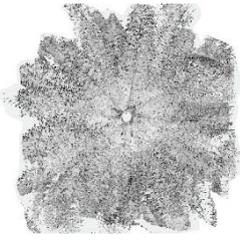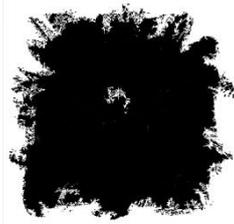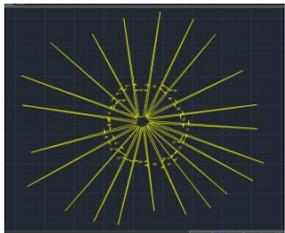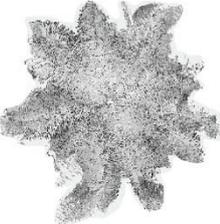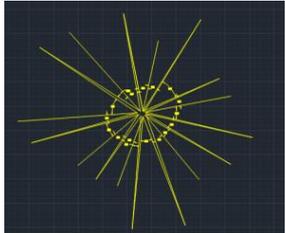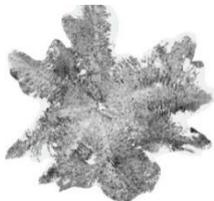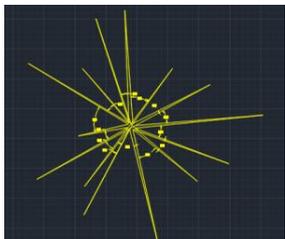
For future works, additional oil palm tree's architecture or parameters could be explored to get a better understanding of the physical attributes of the BSR disease symptoms and

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use it for early detection and severity detection of the disease. The current approach of using four scanning positions for a single tree at a time could be improved by scanning a group of trees using multiple scanning positions. Furthermore, LiDAR sensor could be implemented on a mobile or drone platforms to reduce the time needed for scanning and for larger area application. Meanwhile, the parameters such as frond angle and frond number could be automatically calculated using the deep learning techniques.

Table (3): Correlation between the parameters.

Parameters	Frond number	Frond angle	Crown area	C200	C850
Frond number	1.0000	-0.9389	0.7566	-0.3696	-0.3928
Frond angle	-0.9389	1.0000	-0.7421	0.3136	0.2839
Crown area	0.7566	-0.7421	1.0000	-0.2105	-0.2605
C200	-0.3696	0.3136	-0.2105	1.0000	0.3720
C850	-0.3928	0.2839	-0.2605	0.3720	1.0000

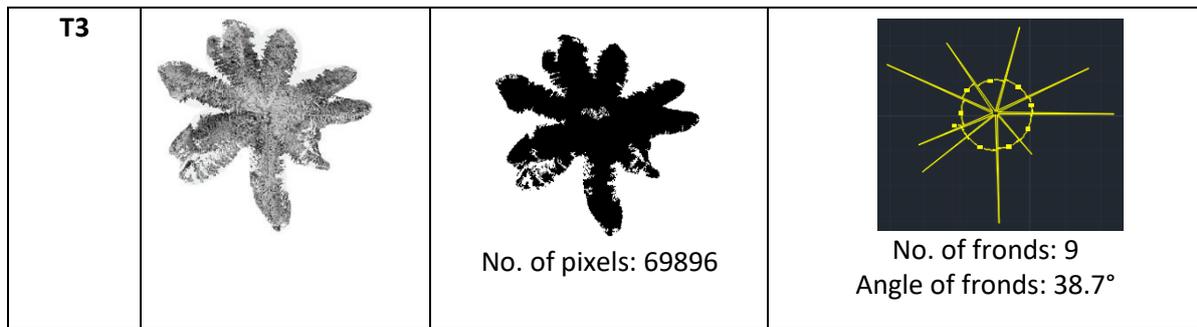| Level	Point cloud	Crown area	Frond properties
T0		No. of pixels : 104896	No. of fronds: 23 Angle of fronds: 14.7°
T1		No. of pixels : 97852	No. of fronds: 17 Angle of fronds: 21.5°
T2		No. of pixels : 75896	No. of fronds: 14 Angle of fronds: 25.3°

T3		
	No. of pixels: 69896	No. of fronds: 9 Angle of fronds: 38.7°

Fig. (4): Examples of crown area and frond top view images according to level of healthiness.

Acknowledgements

Conflicts of interest

The authors declare that they have no conflict of interests.

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