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Research paper

A Rapid Technique in Evaluating Tree Health Using Lidar Sensors

Siti Farhanah Rosli[1], Fazida Hanim Hashim[1,2]*, Thinal Raj[2], Wan Mimi Diyana Wan Zaki[1,2] and Aini Hussain[1,2]

[1]*Electrical and Electronic Engineering Programme*
[2]*Centre for Integrated Systems Engineering and Advanced Technologies (Integra)*
Faculty of Engineering and Built Environment
Universiti Kebangsaan Malaysia, Bangi 43600, Malaysia
**Corresponding author Email: fazida@ukm.edu.my*

Abstract

Crop management is one of the key aspects in precision agriculture. On-site crop management includes a scheduled prediction and prescription of fertilization and pesticide application on specific areas of the field. A prediction of the tree health is much needed in order to decide a suitable prescription for the plant. An autonomous vehicle, equipped with at least one LiDAR (light detection and ranging) sensor, could be used not only for detecting and mapping its surrounding, but to also help evaluate tree health for early distress detection. Currently, farmers have to rely on eyesight to identify trees or plants in distress. Big-scale plantations depend on costly scheduled airborne monitoring routines, which also relies on human vision by scouring through hours of aerial video footage. Both techniques have similar weaknesses in terms of the time it takes to detect a tree in distress and the accuracy of the detection using human vision. The objective of this research is to propose a technique in evaluating tree health using a simple LiDAR sensor that is commonly used in autonomous vehicles. In order to achieve this objective, an evaluation of the different intensity characteristics of tree leaves versus fruits was carried out, both in the lab and in the field. This study has chosen oil palm trees as its subject, as the problem of health monitoring in oil palm plantations is evident. A LiDAR with a 905 nm near-infrared (NIR) laser is used to scan both individual healthy leaves in the lab and different oil palm trees in the field. Since a LiDAR sensor is normally used for ranging, a systematic process was proposed to capture the reflected intensity value of the laser beam that was transmitted to the object. This whole system can be realized using a LiDAR sensor, servo motors, and an Arduino board. Processing software was used to test and store the captured information from the sensor. Later, MATLAB was used to plot the intensity map of the leaves and oil palm tree, classify the range intensity into histograms, and calculate the leaf area index (LAI) for the oil palm trees. From the experimental results, it is found that the reflectance intensity of the leaves shows consistent range values between 155-160 magnitude both in the lab and in the field. From there, three different trees with different number of leaves were scanned and evaluated based on their LAI values. The health of the tree is then predicted, where a healthy tree is estimated to have a higher LAI value. The resulting LAI value is found to correlate with the evaluation using eyesight. This proves that although using a single-wavelength NIR laser beam provided by the LiDAR sensor, as compared to multiple wavelengths of a spectrometer, the difference between the oil palm leaves, fruits and the background noise could be determined. In the future, where multi-wavelength laser LiDAR sensors could be possible, more materials could be characterized. In conclusion, detection, mapping, and materials characterization could be done by an autonomous vehicle utilizing a LiDAR sensor, where tree health could be predicted for crop care management.

Keywords: *LiDAR; autonomous vehicles; tree health; intensity*

1. Introduction

The oil palm industry is one of the major contributors to the Malaysian economy. It is no surprise that oil palm trees are planted in large areas measuring in hectares. Because of the wide field factor, farmers are facing difficulties in monitoring the fertility of their crops. Plant fertility plays an important role in ensuring high yield and high quality produce. In small plantations, farmers usually rely on eyesight to monitor tree health. In huge plantations, airborne monitoring routines are usually scheduled to monitor tree health and infections. These airborne monitoring systems are usually costly as it requires service from an imported high-skilled pilot and a chartered airplane. Despite the high cost, this method of monitoring still relies on human vision, where hours of video footages will be scoured through in order to detect infections or deteriorating tree health.

1.1. History of Lidar Scanning System

A LiDAR-based ground scanning system is proposed in this project to help farmers monitor their crops more efficiently with a reasonable cost. LiDAR or light detection and ranging is a remote sensing tool that has numerous applications. Currently, LiDAR is widely used in agriculture, specifically for creating multi-dimensional digital models of farms, which in turn produces an accurate map of the natural resources [1]. In addition, LiDAR has the potential to identify environmental variations such as canopy height, slope elevation, erosion, water flow, vegetation, etc. This

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is materialized by incorporating LiDAR with an airborne surveying system together with differential GPS and inertial navigation system. The output scanning forms a point cloud where every point has an x, y, and z coordinate together with a number of attributes such as classification, intensity, scan angle, and return number. Gutierrez et al. in 2001 defines that in Airborne Laser Swath Mapping (ALSM), the height can be detected using three sets of data: the range of the laser, the position and orientation of the platform and the calibration data [2]. Besides that, the orientation information received refers to Inertia Measurement Unit (IMU), which contains three orthogonal accelerometers and gyroscopes, as shown in Fig. 1.

Besides ranging information, a laser pulse can also be measured by its returning signal strength, which carries information on the backscattering characteristics of the surface [3-8]. For this project, a ground LiDAR-based scanning system is proposed to measure tree health effectively, without the complexity of an airborne scanning system. Distance measurement requires very precise measurements on the ground that supports the detection scanner surface refractive correction, scale correction scanner, and adjustment time. LiDAR sensor uses Near Infrared (NIR) spectroscopy to record the backscatter energy reflected from the target, and it is referred to as the intensity data by Kaasalainen et al. in 2005 [5]. The particular Lidar Lite V2 sensor that is used for this project is a low-cost LiDAR sensor which transmits a NIR laser beam of 905 nm wavelength. LiDAR sensor can produce a 3-D point cloud "picture" of the surface or object with a high resolution. Therefore, the objective of this study is to identify the intensity value of oil palm leaves by using a low-cost LiDAR-based scanning system mounted on a ground vehicle. The reflected waveforms are influenced by different characteristics such as changes in range and elevation, and reflections due to the material characteristics of the object. To interpret the received waveform laser pulse, basic understanding of the physical background pulse propagation and interaction surface is important. The waveform of each laser pulse can be described with a combination of range and amplitude range. Depending on the waveforms, it can produce one or more parameters on the Gaussian curve [9-11]. In the next section, we will discuss the methodology in building a LiDAR-based ground scanning system and the process involved to analyze the intensity data. The results and analysis of the fertility of oil palm trees are discussed in the results and discussion section.

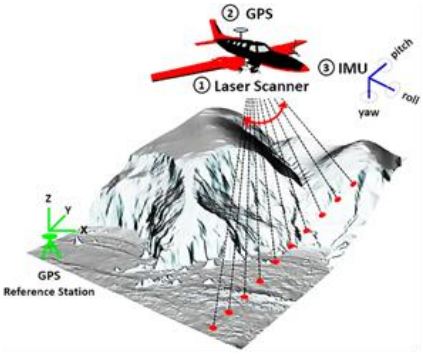


Fig. 1: Airborne Laser Swath Mapping
Source: (Ivan Tomljenovic, 2015)

1.2. Classification Techniques for Intensity-Based Images

In recent researches, classification of images are usually done by combining information from a laser with information from images such as images from different spectrums (thermal and visible), satellite images, digital elevation models (DEMs), textured images, etc. More focus is given to attaining high accuracy data with less noise. Song et al. in 2002 studied different resampling techniques for converting point cloud data from LiDAR sensors to grid image data to reduce noise in the original image [12]. Intensity data from the LiDAR sensor however could be influenced by the reflection surface, moisture content, surface texture, and other attributes of the surface of the object. According to Donoghue et al. in 2007 and Langford et al. in 2006, the geometric dynamics between the sensor and the object could also influence the reflected intensity. Examples of the geometric dynamics are the distance between the object and the sensor, the orientation of the sensor, and the scanning angle of the sensor [13-14].

1.3. Leaf Area Index (Lai)

Leaf area idex (LAI) was first denfined in 1947 as the total one-sided area of leaf tissue per unit ground surface area [15]. Jonckheere et al. in 2004 concluded that the LAI could be defined as half the total developed area of leaves per unit ground horizontal surface area [16]. Different definitions of LAIs could lead to differences in values and interpretations. LAI is a dimensionless quantity, and for this research, LAI is defined as [17]:

$$Leaf\ Area\ Index(LAI) = \frac{No.of\ point\ cloud\ of\ leaf}{No.of\ point\ cloud\ of\ leaf + No.of\ point\ cloud\ of\ fruit} \quad \textbf{Eq. 1}$$

2. Methodology

2.1. Equipment and Software Integration

This study is divided into two parts: object scanning and data processing. Fig. 2 shows the flowchart of the research methodology. A LiDAR-based scanning system for ground vehicle is proposed and designed using a low-cost LiDAR Lite V2 sensor, Arduino Uno microprocessor, power supply, and servo motors to regulate the scanning patterns of the system. Fig. 3 shows the developed LiDAR scanning system. Matlab is used to integrate the 3D point cloud data with the intensity data retrieved from the scanning system [18]. Sawtooth scanning pattern is the scanning pattern chosen for this project as it is sufficient to provide the 3D point cloud mapping of the object in view [17-18].

Two separate locations were chosen for the experiments to be performed: in an indoor setting of a laboratory, and on-site in the oil palm field plantation during day time. The scanning system was placed at a distance of 30 centimetres from the object in the indoor setting. For the on-site setting, the scanning system was placed at a distance of 4 metres. The different lighting conditions are useful to eliminate the possibility of bias towards a specific lighting condition. The scanning was done using the LiDAR scanning system on-site in UKM Khazanah's oil palm plantation field, on different trees with different number of leaf fronds. The same experiment was done in the lab on green oil palm leaves collected from the same plantation field, but in a closed-box experimental setup, to eliminate background noise.

After the collection of data, data processing and analysis were carried out. The scanning process requires an interface to display the point cloud data and saving data information from the LiDAR sensor. For that reason, an open-source software called Processing was used to read the data from the scanning process before producing an intensity map. In this study, the scanning process was performed in two different places which are an indoor laboratory and the oil palm field. Matlab mathematical software was used to plot the intensity map and histogram for comparing different intensity values. This mapping is used to compare the original image of a palm tree with the intensity information values collected from the green leaves. By using the same information, the formula for leaf area index (LAI) is introduced to calculate the leaf area index

for different oil palm trees. Finally, with all the data obtained the fertility of oil palm tree is predicted.

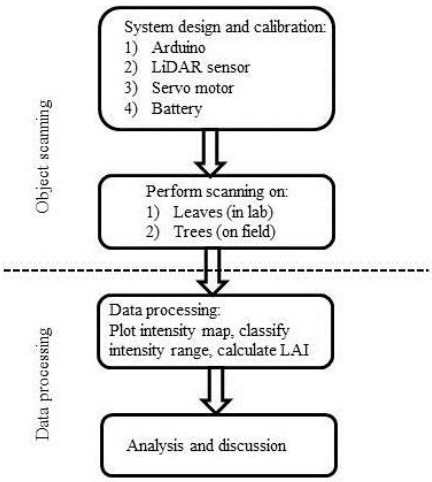


Fig. 2: Flowchart of research methodology

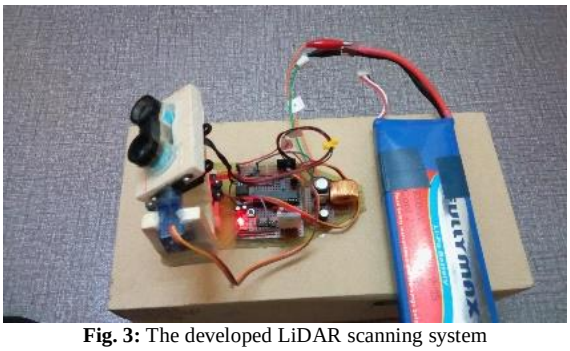


Fig. 3: The developed LiDAR scanning system

3. Results and Discussion

3.1. Outdoor Tree Scanning

For the experiment in the field, LiDAR scanning was performed on three different oil palm trees as shown in Fig. 4 (a), (b) and (c). Each tree has different number of leaf fronds with the values shown in Table 1. Tree 3 has the highest number of leaf fronds as compared to tree 1 and tree 2. The LiDAR scanning system was placed 4 meters away from the oil palm tree.



a)



b)



c)

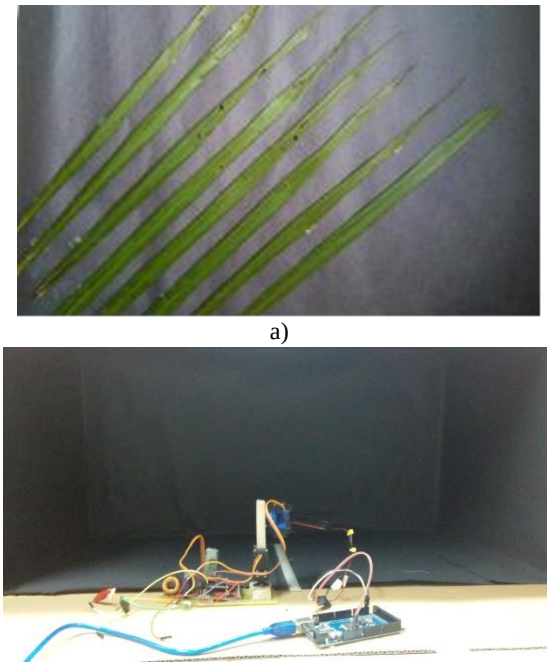
Fig. 4: Oil Palm Tree a) Tree1, b) Tree 2, c) Tree 3

Table 1: Number of leaf fronds of oil palm

Tree number	Number of leaf fronds
Tree 1	20
Tree 2	25
Tree 3	28

3.2. Indoor Leaf Scanning

A similar experiment is later performed in an indoor laboratory. In this experiment, green leaves extracted from the same oil palm plantation were scanned. For this experiment, the LiDAR scanning system was placed 30 centimeters from the platform with green oil palm leaves. A closed-box experimental setup was designed for this experiment to eliminate background noise. Black paper was chosen as the background to reduce noise and reflections during scanning. Fig. 5 (a) and (b) show the placement of green leaves against a black background and the LiDAR scanning system.



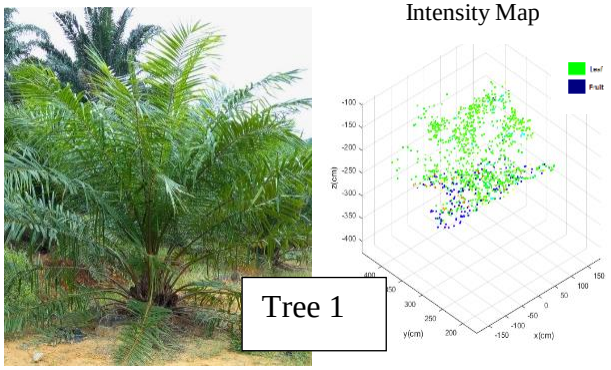
a)

b)

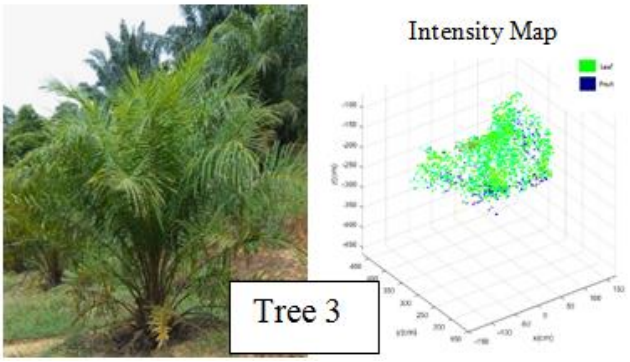
Fig. 5: (a) Green leaves with background and (b) Setup for green leaves indoor scanning

3.4. Intensity Mapping, LAI, and Histogram Analysis

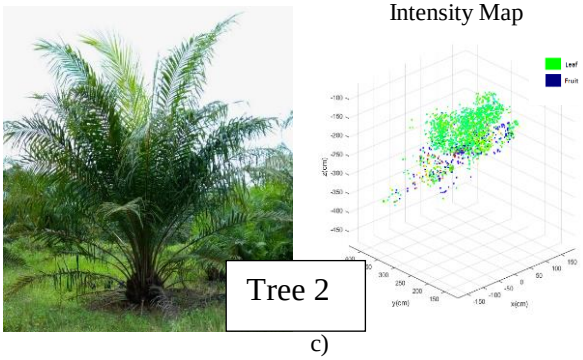
After the scanning process is completed, the data is saved in a text file and is used to plot the intensity map and histogram of different intensities. Fig. 6 (a), (b), (c) and (d) show the intensity map for the three oil palm trees and green leaves. The different colours of point cloud in the intensity map represent the intensity range obtained from the LiDAR sensor. The intensity range of green leaves is shown in Table 2. We classify the intensity range of green leaves in the intensity map for all three oil palm trees and green leaves as green colour. This value is important to calculate the leaf area index (LAI) for tree 1, tree 2 and tree 3. We can see that, tree 3 has the most green colour point cloud data on the intensity map. Table 3 shows the value of leaf area index of the three oil palm trees, using Eq. 1. Note that, tree 3 has the highest value of leaf area index compared to tree 1 and tree 2. To get a clearer picture, a graph of leaf area index against the three oil palms trees is plotted as shown in Fig. 7. Therefore, we can simply predict that tree 3 is most fertile as compared to tree 1 and tree 2, due to the highest number of leaf fronds.



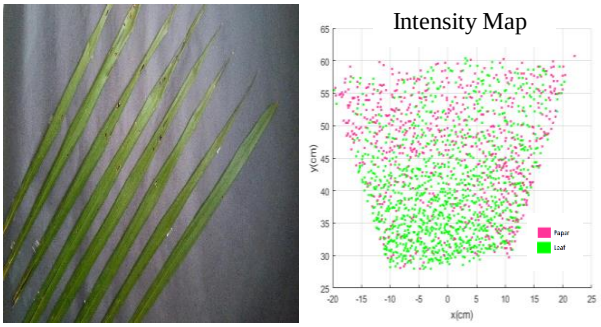
a)



b)



c)



d)

Fig. 6: a) Intensity map of oil palm tree 1, b) Intensity map of oil palm tree 2, c) Intensity map of oil palm tree 3 and d) Intensity map of green leaves

Table 2: Intensity range for green leaves and background

Types	Intensity range
Green Leaves	155-160
Background	167

Table 3: Leaf area index for tree 1, tree 2 and tree 3

Types	No. of point cloud of Fruit	No. of point cloud of Leaves	Leaf area index (LAI)
Tree 1	691	1099	0.3860
Tree 2	644	928	0.4094
Tree 3	768	968	0.4424

Fig. 7 shows the LAI plot for all trees. It is shown there is a correlation between the LAI and the number of leaf fronds on each tree, where the tree with the highest number of leaf fronds has the highest LAI while the tree with the lowest number of leaf fronds has the lowest LAI. This comparison validates the LAI approach in determining the number of leaf fronds within each tree.

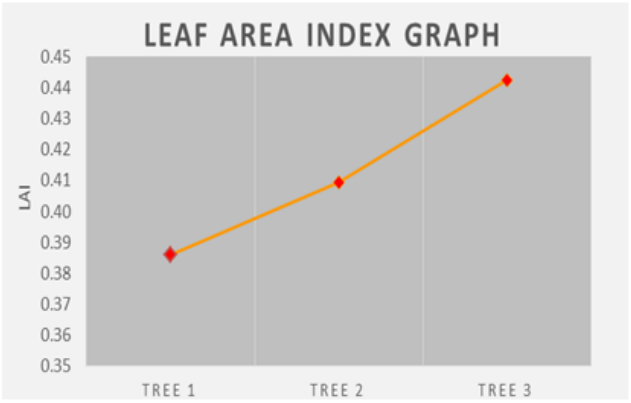


Fig. 7: Graph of Leaf Area Index of palms oil

4.0 Conclusion

As a conclusion, this study highlights the ability of the intensity data obtained from the LiDAR sensor to predict the health of oil palm trees. It is shown that the experiments give consistent results both in the lab and in the oil palm field. In addition, the leaf area index obtained from the experimental work shows promising results in future investigation for rapid assessment of tree health. This study also suggests future work in utilizing both ranging and intensity data from different IR laser wavelengths (in addition to 905 nm wavelength) to get a more accurate information of the oil palm trees.

Acknowledgement

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